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Sailing with Halley's comet— and other space spectaculars for the 1980s

The Jet Propulsion Lab's imaginative package includes a space sail that needs no fuel, a radar mapper to see through the clouds of Venus and rovers to explore Mars.

by John F. Pearson
SCIENCE EDITOR



As any bird watcher would be quick to confirm, purple pigeons don't exist. Not yet. Right now they fly only at the Jet Propulsion Laboratory—in the brains of scientists and engineers, in computers and on drawing boards. Still, they're a remarkable flock of birds.

Planners at JPL use "purple pigeons" as a tag for the unmanned missions they hope to launch in the 1980s. The projects would aim at further exploration of our solar system and would use—with one exception—spacecraft of conventional design. The one exception—the solar sail—is unlike anything ever put into space.

On a recent visit to the laboratory in Pasadena, Calif., I heard administrators, scientists and engineers talk enthusiastically about the sail, describing it as an exciting scien-

Photos and data from space flow into control center (left) at the Jet Propulsion Laboratory, Pasadena, Calif., as scientists monitor and guide missions within the solar system. Above: Solar sail nears Halley's comet in painting by Ken Hodges.

Countdown to new space spectaculars

The men who gave us the Viking mission to Mars—scientists and engineers at the Jet Propulsion Lab—are cooking up new unmanned space spectaculars for the '80s. Here's a sampling of their way-out plans.

Beyond 1980s

When manned exploration of Mars becomes feasible, solar sails (right) could be used to land small powerplants, space vehicles and other vital payloads.



1981-1983

Radar-equipped orbiter (below) could penetrate dense clouds that hide mysterious Venus from standard cameras. At a distance of 525 miles, the orbiter could map planet's entire surface. An instrumented landing package could be dropped on the planet to carry out scientific studies.



VENUS

1984

As a follow-on to Viking mission, small rovers would be landed on Mars to explore canyons, craters and other areas of geologic interest. The Vikings on wheels could cover about three miles a day, returning photos and scientific data via a mother orbiter:



JUPITER

GANYMEDE

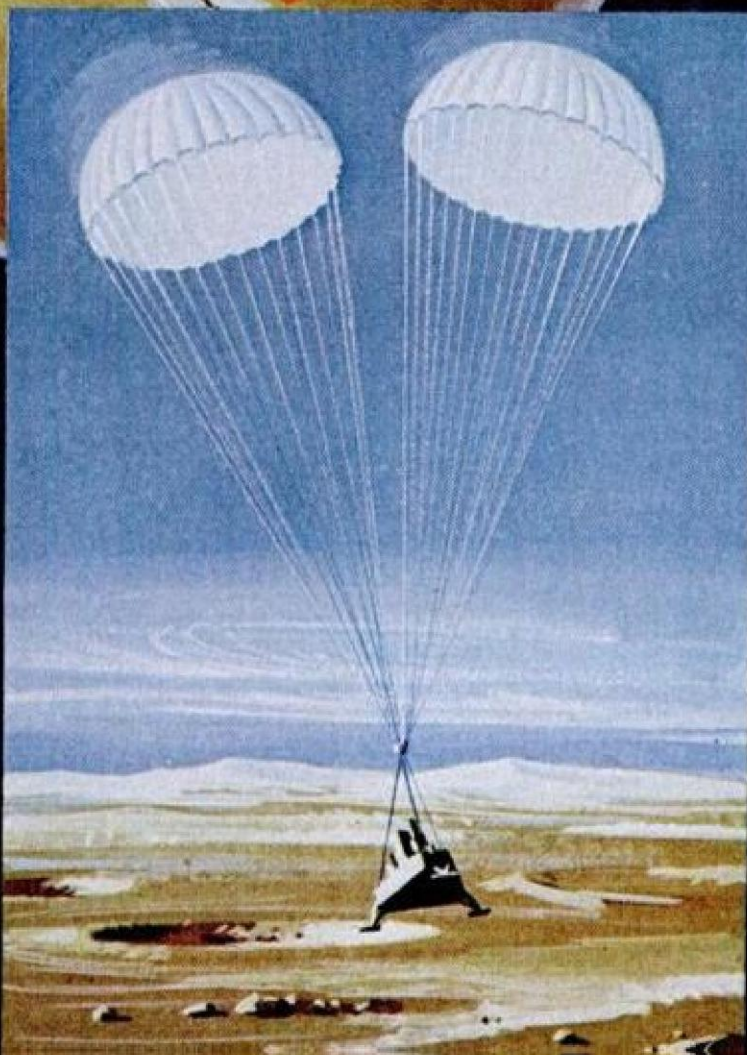
SATURN

TITAN



1980s

The frozen surface of Ganymede—one of Jupiter's large moons—is cracked by impact of small lander. Scientists say that it could be dropped from orbiting spacecraft sent to Jupiter and on a cruise of that distant planet's four major moons.



1980s

Spectacular Saturn has an Earthlike moon—Titan—with a heavy atmosphere. NASA and JPL scientists propose sending a Viking-type vehicle to search for possible life forms. Small lander would descend on Titan while mothercraft, in orbit around Saturn, would study planet.

tific concept as well as an idea that could stir the public interest.

The public's involvement is an important consideration with the people at JPL. This reflects the view of the lab's new director, Dr. Bruce Murray, who last spring created a task force to review old and new mission concepts and to debate their scientific value, feasibility and "pizazz." The idea was to weed out missions with little public appeal—"gray mice"—and focus on those that gave promise of drama and excitement—"purple pigeons."

Manned space ventures have built-in drama. Few TV viewers who watched Neil Armstrong take his first step on the moon will forget that exciting moment. There was great achievement in that step, but danger, too. In the back of the viewer's mind was the thought, "What if something goes wrong?" A mere machine on the moon would have been another story.

Machines are best bet

But for the foreseeable future, the only way we can explore the planets is with unmanned machines. As yet, we don't have the technical capability to send men to distant worlds. Besides, manned missions are far more expensive to mount than unmanned ones.

So the purple pigeons—or some versions of them—will be the way we'll explore the planets in the decades ahead. These missions will build on the technology and lessons learned from Viking and earlier projects. Viking was a much more difficult and sophisticated venture than Apollo. Landing men on the moon—in our own back yard—was easy compared to the task of sending a vehicle 460 million miles for a soft landing on Mars. The excellent photos of the Martian landscape produced by the Viking landers offer solid proof that machines can do a job in space.

When it comes to designing, pro-

include at least several of the purple pigeons. The most unusual project of the whole flock has to be the solar sail. It was explained to me by Norman R. Haynes, a friendly, bouncy young man who clearly enjoys his work as manager of advanced programs development.

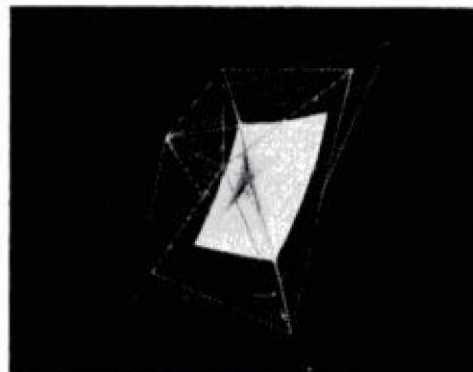
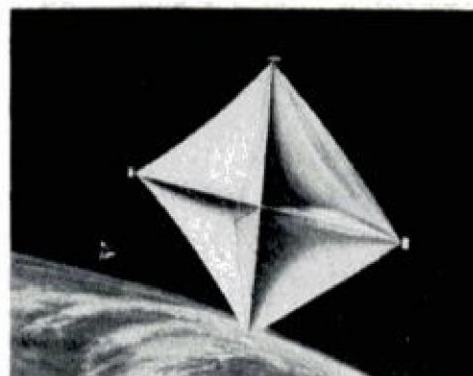
Photons, he told me, are what make the sail work. Scientists define photons as massless particles that carry energy and have momentum. When reflected, they change momentum and a force is exerted against the reflecting surface—like a wind against a sail. As photons stream out from the sun—and they are not to be confused with the solar wind, a flow of ionized hydrogen and helium—they have a measurable effect on objects they hit.

"When you calculate the trajectories to get from the Earth to Mars," Haynes explained, "you have to allow for the amount by which the craft is going to be pushed off course by photons—sunlight pressure. It will amount to from 10,000 to 20,000 kilometers. Keep in mind that the typical spacecraft is small and dense. If you have a craft that's very large and very light, it gets pushed around that much more."

A big plastic kite

JPL scientists envisage a squarish sail measuring about half a mile on a side. It would be made of thin plastic film coated with aluminum to create a highly reflective surface. The sail would be supported by lightweight metal spars and look like a giant kite. At its center where the long spars are joined, a conventional spacecraft (such as a Mariner or Pioneer) would be attached. It would contain computers, communications gear and sensors.

Initially at least, the sail would be launched from a Space Shuttle Orbiter circling the Earth at an altitude of about 500 miles. Folded into a compact package, the sail would be removed from the Orbiter's



One way of turning the sail is to deploy small vanes at the corners, as shown in top illustration. Vanes would be controlled by onboard computer. Above: Following Earth launch, spars are extended and sail is in process of unfurling.

ing speeds as great as 35,000 mph.

Rocket propulsion systems have fuel limitations that rule them out for missions of long duration. Until the sail came under study, NASA was concentrating on another concept: solar electric propulsion. This system uses solar cells to convert sun power into electricity. The electricity is then used to ionize a propellant—vaporize it into individual atoms. The atoms are fed into engines that accelerate them out through the back of the spacecraft, providing thrust.

Big decision coming up

"It appears that by the end of this fiscal year NASA will make a decision on which system—solar electric or solar sail—will go into development." That's the opinion of Jerome L. Wright, manager of JPL's solar sail task force. "It isn't likely," he explained, "that both will be developed. They're just too close in performance to justify that. NASA will probably go with the one that offers the greater mission application, better performance, lower cost and the wider public appeal."

Wright thinks that the sail may have a significant performance advantage over solar electric propulsion for long-duration missions. "Except for its attitude control system," he said, "the sail is completely passive. It doesn't generate electrici-

Future space exploits will surely include at least several of the purple pigeons. The most unusual project of the whole flock has to be the solar sail.

gramming and guiding unmanned space systems, no other group anywhere in the world can match the achievements of the people at JPL, a NASA-supported facility. JPL's experience goes back to the Pioneer, Ranger, Surveyor and Lunar Orbiter missions. In 1964, Ranger 7 sent back 4308 photos to give us our first close look at the moon.

Future space exploits will surely

cargo hold and deployed like a huge umbrella, with small motors pulling the spars out to their full length and stretching the sail over the framework. Then sunlight pressure would act on the sail, pushing it away from Earth in a spiralling orbit. Though the sail would be a relatively slow vehicle, at least as space speeds go, scientists calculate that it should be capable of attain-

ty, there are no ions being accelerated, there's no exhaust."

The sail could become the reusable interplanetary shuttle of the future. It could deliver payloads to the inner planets—Mercury, Mars and Venus—and return to Earth with scientific samples, delivering them to an Earth-orbiting lab. JPL scientists calculate that the sail could carry a 10-ton payload to Mercury and at least 5 tons to Mars.

The system could also be used for missions to asteroids and comets, and for swing-by missions to the outer planets. (But the sail's performance at the outer reaches of the solar system would be diminished because of the weaker sunlight pressure there.)

Tacking toward the sun

Even though the sail is pushed by energy radiating from the sun, it would still be capable of flying toward the sun. The sail would turn so that it would "tack" into the photon stream. Two methods are under study for turning the sail. In one, lanyards pull in the outer edge of one side of the sail, creating an imbalance. As a result, a greater solar pressure is exerted on the fully extended side, causing the sail slowly to change attitude.

The second method would employ four small vanes, one at the tip of each diagonal spar. Control would be achieved by deploying two vanes on the same side, for example, and leaving the other two in the "down" position. The deployed vanes would create the desired imbalance. All such operations would be under the control of an onboard computer.

A rendezvous with Halley's famous comet is under consideration as the sail's first mission. It's a difficult feat—the comet is a high-velocity object with an orbit in the opposite direction from Earth's—

but the sail, scientists say, has the unique capability to do the job. Once in orbit with the comet, the sail would be jettisoned, and the instrumented spacecraft it had carried would tag along in the comet's gaseous tail.

To make the rendezvous, the sail must be launched in 1982. It would encounter the comet in March 1986—34 days after the comet makes its closest approach to the sun.

I asked Jerry Wright why JPL

'We'd like to have an electron microscope aboard for a look at those dust particles. We'd be seeing particles formed at the birth of the solar system.'

had such an interest in comets. "You might say that they have been in cold storage since the birth of the solar system," he said. "Particles that were formed then are still in the comet and are unchanged. No planet remains unchanged. Halley's is the biggest, most active comet we have any chance of getting to."

Dust, rocks and gases

He explained that comets have two main constituents: rocks and dust, and frozen gases. When the comet nears the sun, the gases vaporize, creating a bright coma at the comet's head and a fiery tail.

"The gases pull dust with them—and everything gets blown out into space," Wright said. "Instruments on the spacecraft would collect samples of what comes out. We'd like to have an electron microscope aboard for a look at those dust particles. We'd be seeing particles formed at the birth of the solar system."

The other purple pigeon projects high on the JPL list include:

■ Four small automated rovers to explore Mars. This would be a logi-

cal extension of the Viking Lander missions. The vehicles would be equipped with cameras, "mini-labs" and manipulator arms for sample acquisition and handling. They would travel in pairs so they could work together in certain experiments. A good time for launch, according to JPL scientists, would be in February 1984.

■ A spacecraft launched in 1983 would arrive at Jupiter in 1985 for an inspection tour of its four major

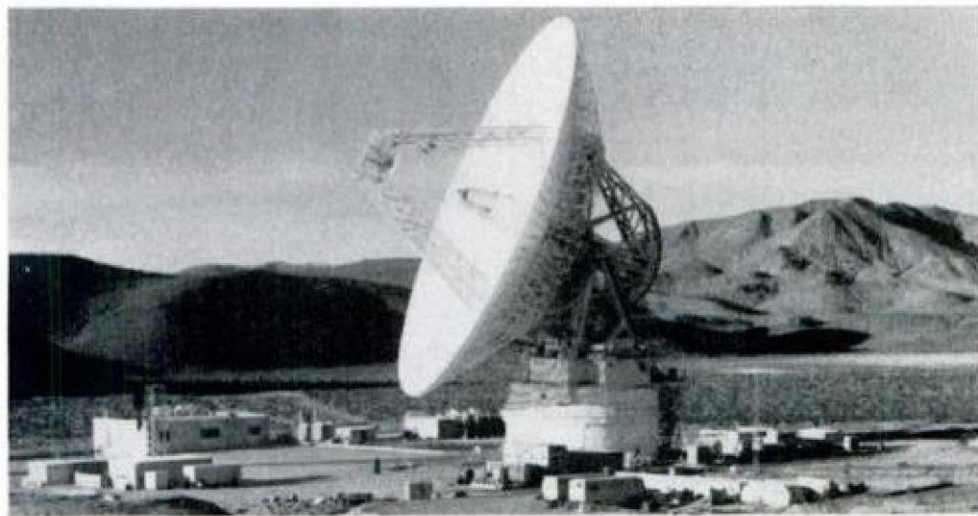
moons (first discovered by Galileo). Photos of their surfaces would be obtained and overall chemical compositions determined. Finally, the orbiting spacecraft would drop a lander on the moon Ganymede, establishing an observatory there capable of studying the planet as well as its other moons.

■ Saturn and its planet-sized satellite, Titan, have long interested astronomers. A spacecraft launched at the earliest opportunity, 1985, would arrive at Saturn in 1990. Saturn is nearly a billion miles from Earth. In orbit around the planet, the spacecraft would observe Saturn's rings, atmosphere, radiation environment and satellites. After a few weeks, a daughter spacecraft would separate from the mother ship and land on Titan.

"Titan is probably the most interesting satellite in the solar system," Norman Haynes explained to me. "Almost the size of Mercury, it has a thick atmosphere containing hydrogen and methane—gases in the Earth's original atmosphere. The surface probably contains a lot of water, frozen solid. These are all conditions that indicate a possibility of life."

■ A spacecraft could be placed in a circular orbit around Venus as early as 1981, but another good opportunity appears in 1983. The craft would use a scanning radar system to map the planet's cloud-covered surface.

Though JPL scientists have come up with other new missions, the five purple pigeons described here are the ones they're most enthusiastic about. All five are scientifically sound and aimed at increasing our knowledge of the solar system. The possibility of learning more about how the Earth was formed should interest the American public. At least that's the hope of the space experts at JPL. ★★★



The weak signals from distant spacecraft are picked up by this 210-foot-diameter dish at Goldstone, Calif. Similar antennas in Australia and Spain take over as Earth rotates.

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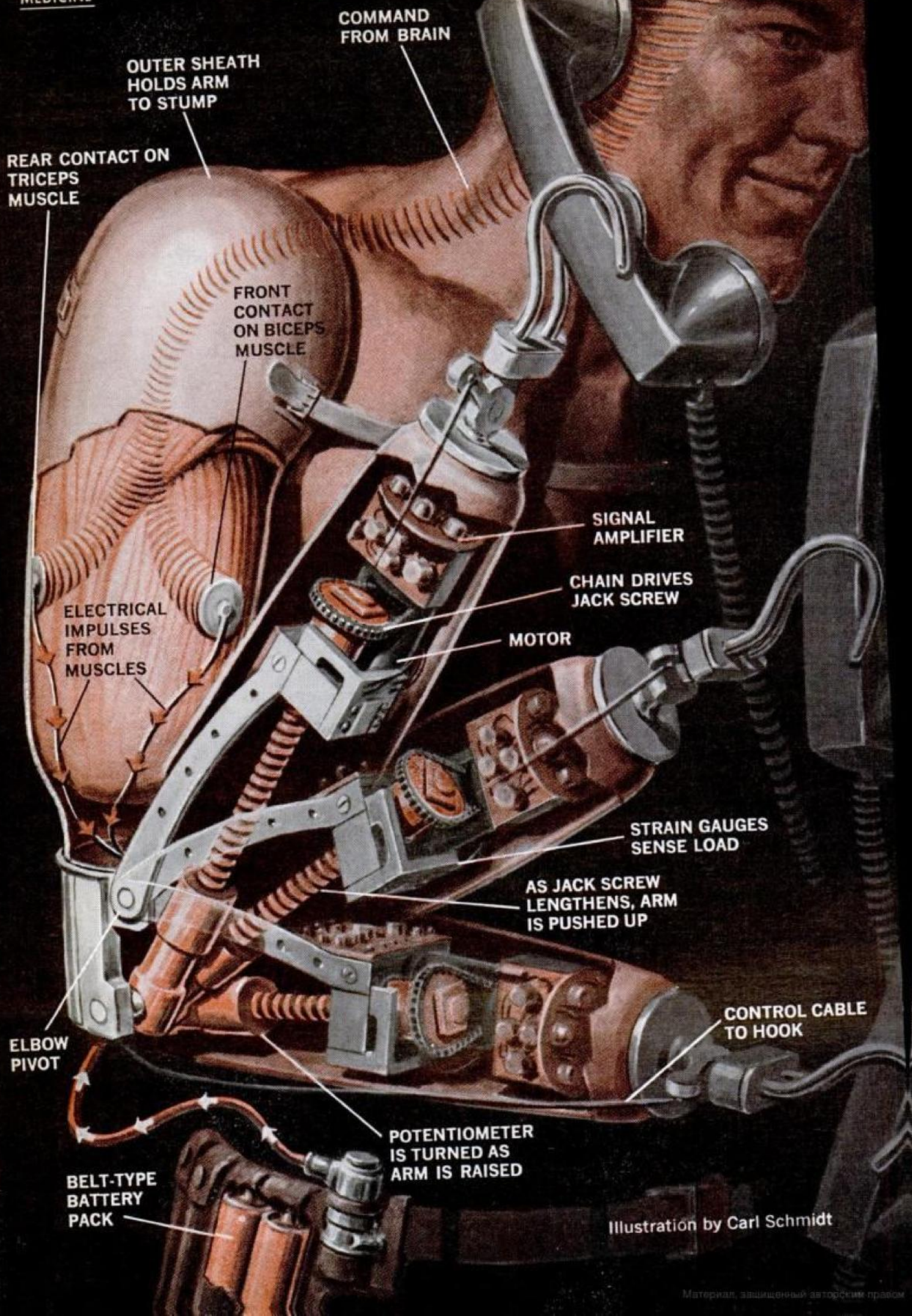
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THE AMAZING 'BOSTON ARM'

An ingenious new artificial limb taps the body's own electrical impulses to respond like a real one

By ARTHUR S. FREESE

THE MAN BELOW is picking up a telephone with an artificial arm controlled by his thoughts alone. If he "wills" the arm up, it comes up; if he "wills" it down, it will straighten out. For all practical purposes, he controls the mechanical limb in the same way he would a real one—by command signals from the brain that tell the body's muscles what to do.

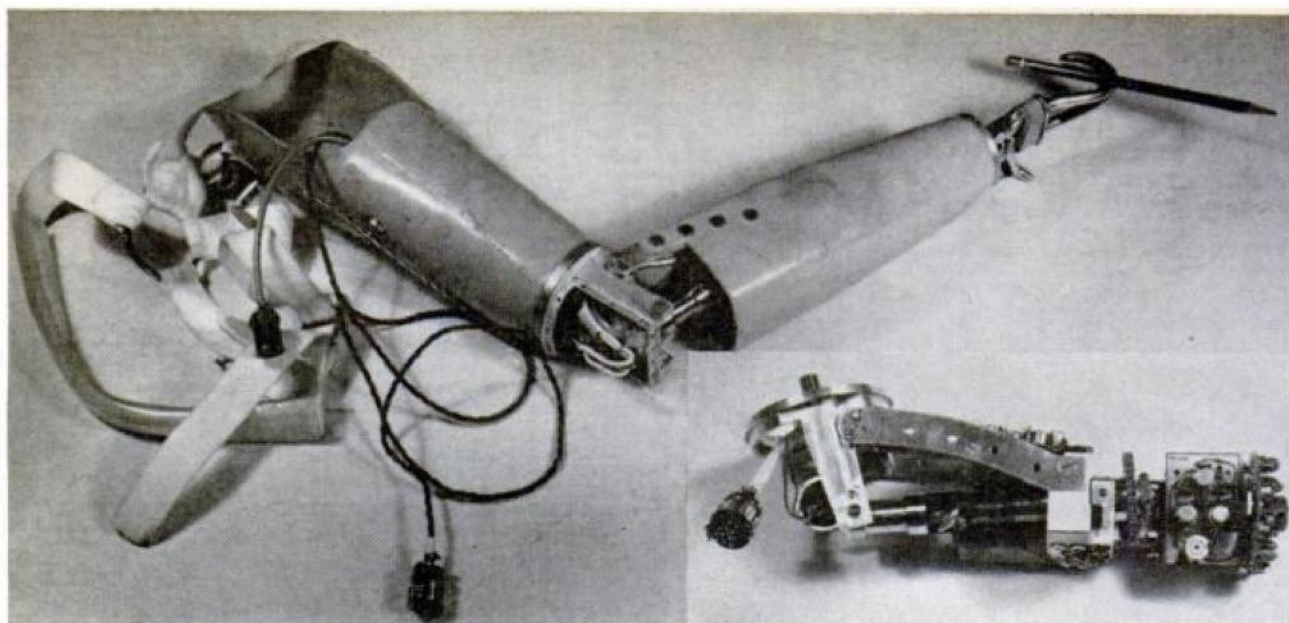
This amazing device, developed in Boston by a team of doctors, engineers and electronic experts, has become known as the "Boston Arm." It brings new life and hope to hundreds of thousands of upper-arm amputees—those who have had an arm removed below the shoulder. So long as some of the original arm muscle is still intact, the

new arm will work. What it does is use the electrical energy generated by the old severed muscles in the stump to move a mechanical linkage substituting for the lost arm.

Using the new artificial limb, an amputee can pick up a cup of water and drink it, answer the telephone, move objects in any direction, even lift a 10-pound weight. This is only the beginning, too, because a basic breakthrough has been made—otherwise useless muscles can now perform important tasks. If severed muscles in an arm stump can move a hand to answer the telephone, other muscles in the body may be harnessed to let a

CUTAWAY shows how ingeniously simple screw jack arrangement raises and lowers arm like a car jack. Tiny motor turns screw according to electrical signals from real muscles—the greater the muscle voltage, the faster the arm moves. Strain gauges measure weight on arm so user can tell how heavy a load he is picking up. Potentiometer at elbow pivot senses speed of movement by its changing resistance





IN COMPLETED ARM, the mechanical and electronic components are encased in a flesh-colored fiberglass sheath covering all but the elbow pivot. Upper-arm section is slipped over the amputee's stump and held by shoulder straps. Inset photo at right shows motor, jack screw and electronic control circuitry that are hidden inside the forearm section



PICKING UP A BOX with two hands, one real and one artificial, an amputee shows how the mechanical device is so sensitive he can easily balance the weight between the two to keep the box level. The amount of muscle tension required to lift the box is determined by strain gauges inside the device

legless person walk or a paralytic victim move.

These exciting possibilities come from the new ultrasophisticated technology of bioengineering—literally combining human and mechanical functions into single living systems. Dr. Melvin J. Glimcher, professor of orthopedic surgery at Harvard University, is a principal developer of the new prosthesis—artificial replacement—along with Prof. Robert W. Mann of the Massachusetts Institute of Technology and the National Academy of Sciences.

Their work comes at an important time for thousands of amputees returning from the Vietnamese War, plus the estimated 1500 or so amputees produced annually in this country through auto and other accidents. Doctors working in rehabilitation centers have long been aware that many amputees are reluctant to use the older type of replacement arm. Operated by a complex system of cables and harnesses, it not only is limited in what it can do, but it requires a series of difficult and embarrassing contortions to make it work.

The new Boston Arm works smoothly and naturally. Except for its hook, it might well pass as a normal arm. Eventually, it may be possible to replace the hook with an artificial hand having movable fingers for an even



WITH ELECTRICAL CONTACTS strapped to his arm, author Arthur Freese shows how anyone can operate the artificial limb after only a few minutes' prac-

tice. As he tenses muscles to raise his own arm, test arm clamped to bench begins to rise, too. Mechanical arm follows every move the real arm makes

more realistic appearance. Because the arm works like a real one, little training is required to learn to use it.

To see the Boston Arm, I visited the Liberty Mutual Insurance Co.'s Research Center in Hopkinton, Mass., 25 miles from Boston. I was ushered into a crowded room that looked more like a radio repair shop than a medical research laboratory. The walls and benchtops were jammed with electronic gear, including the TV-like eye of an oscilloscope.

Cord Ohlenbusch, an electrical engineer, and David Russell, a mechanical engineer, had been commissioned by Liberty Mutual to handle the actual construction of the experimental arm under the guidance of Dr. Glimcher, Prof. Mann and Dr. Allen L. Cudworth, director of the Liberty Mutual Research Center. Within two years, they had come up with a practical, working model—the remarkable device that now lay before me on a table.

In the late 1950s, the British and Russians devised an artificial hand controlled by electrical signals from resid-

ual muscles in the forearm. It was, however, merely a simple "go-no go" affair in which the hand—a two-part pincher—could only be opened or closed with no control over strength or speed.

Dr. Glimcher set out to develop a better system. One mathematician he consulted was Dr. Norbert Wiener who in 1948 had introduced his now-famous theory of cybernetics—the study of automatic control and communication processes in both machines and living creatures. This broad new science seeks to find common grounds in operations as diverse as your nervous system and an electronic computer.

Just as the power steering in your car amplifies the force of your hands and transmits it to the wheels, the idea gradually evolved that an electro-mechanical system could be used to amplify the power of once-useless muscles and transmit it to an artificial extension. What happens is this. When you tense a muscle, it generates a tiny electrical current, barely a few thousandths of a volt. The harder you contract the

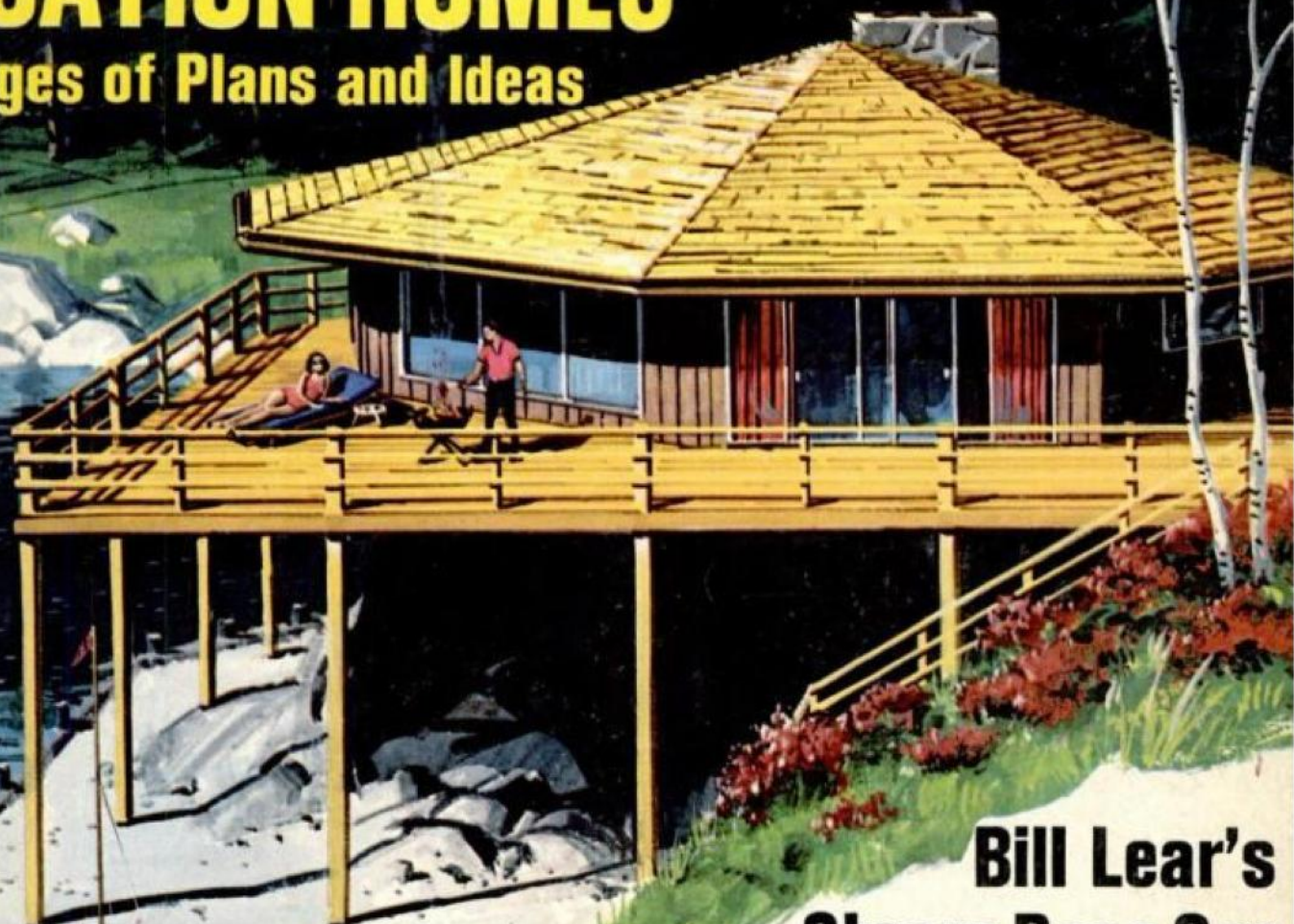
First Report on Ford's 'Answer' to Volkswagen

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The next big
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TAPE YOUR OWN TV SHOWS

By LEN BUCKWALTER



HOME VIDEO RECORDING is not only fun, but can help youngsters improve speech and musical skills



BUILT-IN MONITOR is an added feature on this compact Sony VTR. Below screen is automatic timer

Home video recorders are beginning to crack the price barrier. Here a PM reporter who tried one tells of the fun you can have watching the family on TV, checking your golf swing and taping shows off the air for replay later

TAPE YOUR OWN TV SHOWS?

As little as two or three years ago, experts were saying, in effect, "Don't hold your breath—the home video tape recorder is a long way off." Now the picture is changing rapidly. The home VTR has already broken the \$1000 price barrier, and a dozen makers have models on the market, ready to go.

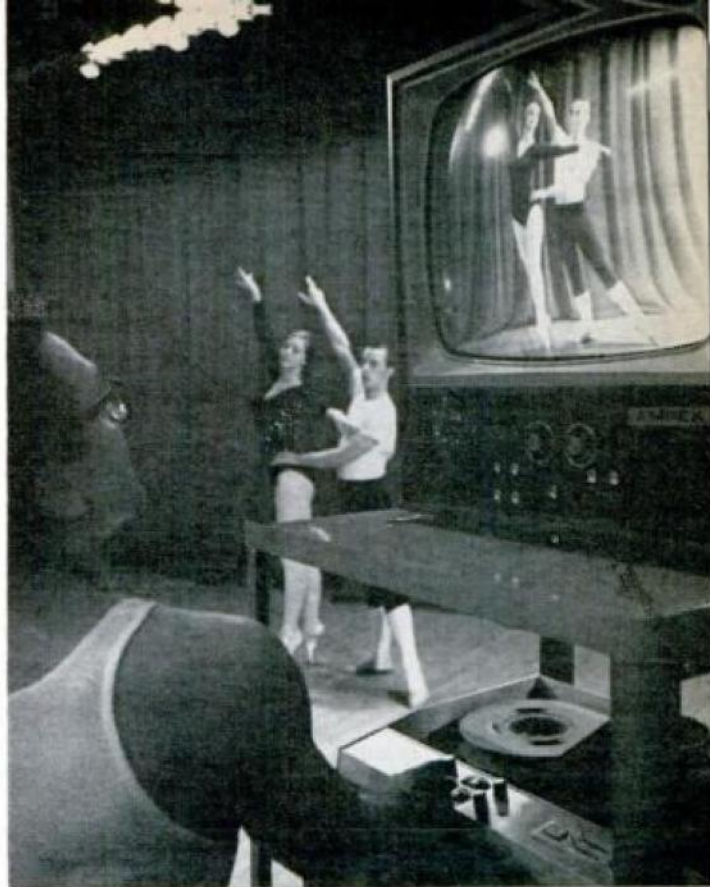
As with a color TV, the price tag is expected to drop quickly when production gets rolling. Five years ago no one thought color sets would catch on; now they're outselling black-and-

whites. The same could happen with the VTR. Manufacturers think the magic number is \$500. When that figure is reached, the home VTR will be off and running. Meanwhile, if you're willing to shell out about what one of the early color TVs cost, you can enjoy video taping right now. The home VTR owes its remarkably fast development to ingenious electronic engineering. When you consider that a professional studio system costs \$100,000 or more, it's amazing that there's a home version at all. Not only are prices dropping, but cabinet dimensions are also shrinking. Today's components are not much bulkier than those in your hi-fi system. There are even some portable models on the market.

Video recording requires three elements: a video camera, a video recording deck and a monitor screen on which to view the pictures. The nice thing about this is that you already own the monitor—your TV set. Most of the present systems on the market are designed to play through a standard TV set or can be adapted to.

Another nice thing is that you don't have to buy the whole system all at once. You can start with just the recording deck. This will let you tape TV programs off the air and replay them at your leisure. Sony, for instance, offers its deck alone for \$695. Later, for a few hundred dollars more, you can add a camera, enabling you to tape your own live-action TV shows right in your living room. Doing it this way is not too much rougher financially than assembling a fine hi-fi system a component at a time.

Although expensive, video recording offers many advantages over home movies. Both sound and picture are recorded simultaneously on the tape. This gives you perfect "lip-sync"—your actors' voices are in exact synchronization with the movement of their lips. Editing a tape is simple because sound and picture run side by side. In movies, the soundtrack runs along a different portion of the film from the



BALLET STUDENTS at a California school perfect their form with help from an Ampex VTR. Instructor tapes dance, then plays it back for them to study

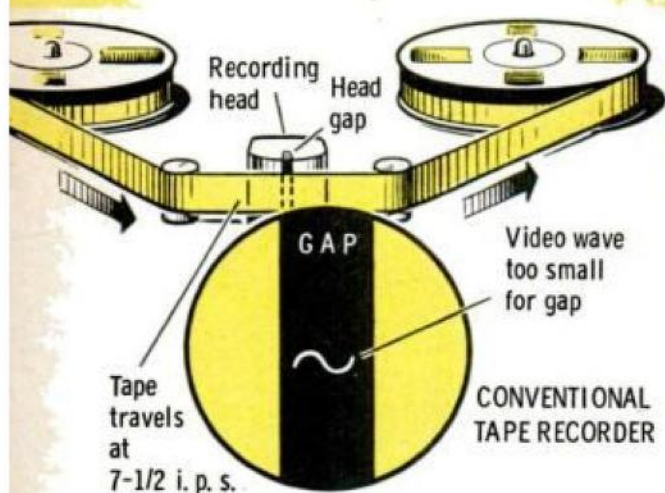


OLYMPIC TRACK STARS are videotaped during time trials to provide visual record for later analysis

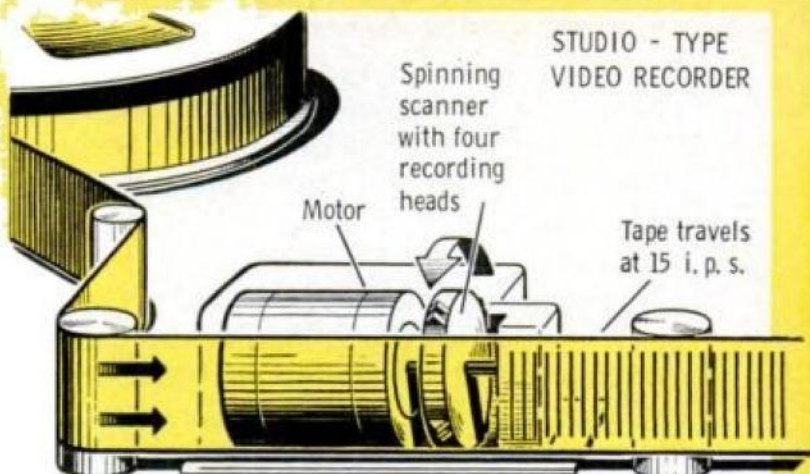


WATCHING REPLAY OF TAPE, Oregon State sprinter Willie Turner (right) discusses form with a coach during preparation for 1968 games at Mexico City

HOW THE BREAKTHROUGH IN THE



CONVENTIONAL TAPE RECORDER is way too slow to record video signals. Video waves, fluctuating millions of times a second, are physically too small to span the gap in the recording head, as shown at left. Speeding up the tape "stretches" video waves



over a greater length, but drastically increases wear and cuts down recording time. The answer is to move the head past the tape, thereby increasing the relative speed between them. In expensive studio systems, four heads on a motor-driven disc are

corresponding picture sequences, making editing difficult.

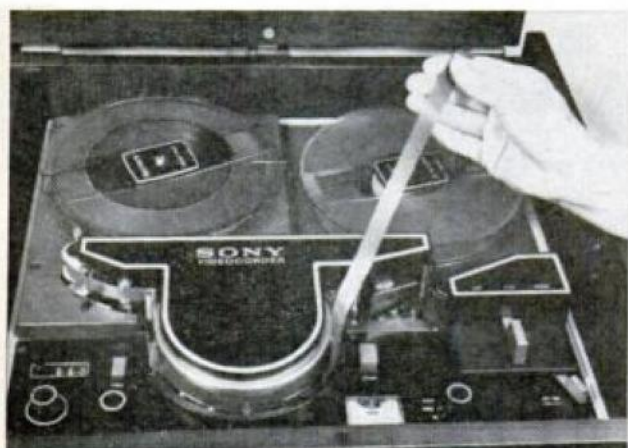
With a VTR, you have instant playback. You can see what you've shot immediately. There's no waiting for film to be processed. If you make an error, such as a poorly lighted scene, you know it on the spot and can reshoot the scene until it's right. If an actor muffs a line, you just erase that section of tape and do it over. There's no waste of costly footage, as with film. When you're tired of a sequence, you can re-record right over it. Tapes can be erased and reused hundreds of times.

For taping programs off the air,

some machines have an automatic timer that lets you set the recorder to go on at a time when you're not home. This way, you can record shows that you otherwise would have missed and enjoy them later when you get home. By taping musical shows and televised concerts, you can build up a library of fine entertainment for showing whenever you want.

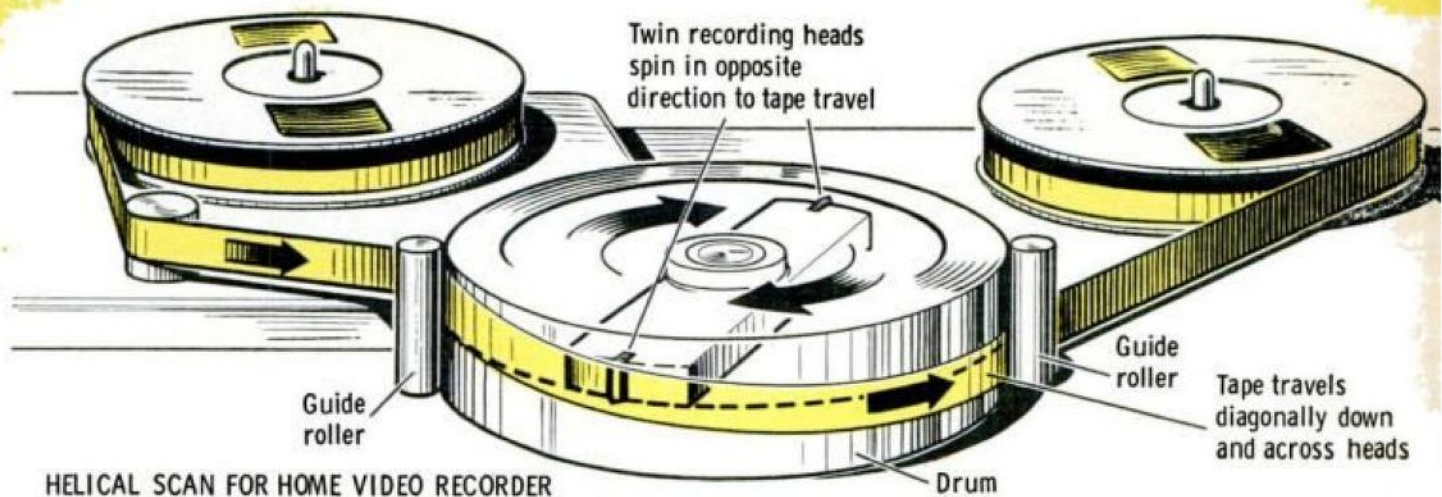
Almost any physical skill that requires form and training can be improved by watching its performance on a TV monitor. Practice your golf swing in front of the camera, then play back the tape and you can quickly see what's causing that hook or slice. Many purchasers of today's VTRs are public figures, mostly actors and politicians (one VTR was reportedly in the White House). The recorder is a fabulous tool for show-business people who want to rehearse or preview their performances while shielded from the critics. A beginners' bowling class in Idaho learns faster when it views mistakes on the TV screen. A charm school in Los Angeles teaches poise, makeup, speech and modeling, helped by a VTR.

Another VTR sharply reduces learning time at an equestrian school by



MOST VIDEO TAPE is half inch wide—double the width of conventional 1/4-inch audio recording tape

SMALL HOME VTR WAS ACHIEVED

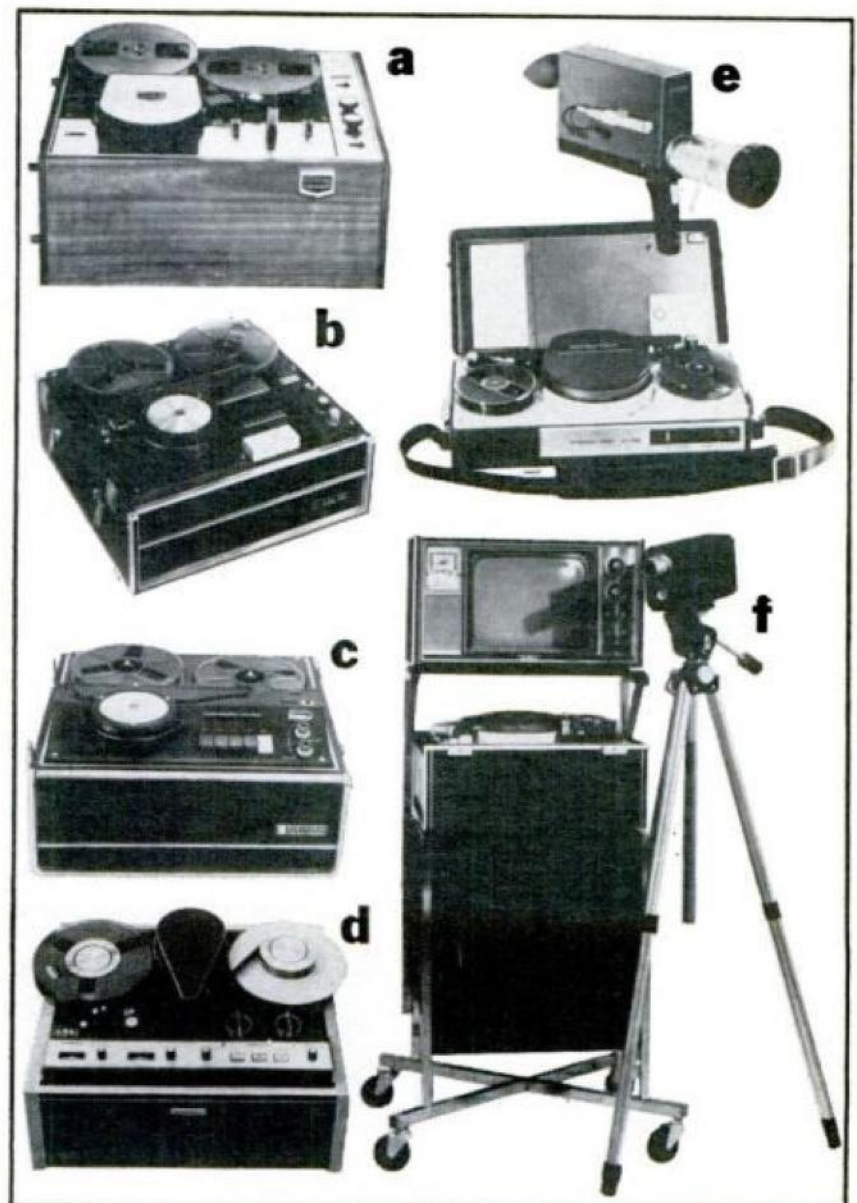


HELICAL SCAN FOR HOME VIDEO RECORDER

spun rapidly across the tape, creating an effective tape-to-head speed of 1500 inches per second at an actual tape speed of only 15 inches per second. This way, video frequencies up to 5 million cycles per second can be recorded. Home-type VTRs

use a modified system called helical scan. Two recording heads spin horizontally while the tape travels diagonally past them, as shown above. This produces a tape-to-head speed of several hundred inches per second—fast enough for home recording

CURRENT CROP OF VTRs includes many shapes and sizes, from lightweight, battery-operated portables you can sling over a shoulder (E) to a complete, mobile TV studio you can roll from room to room (F). Most common form is separate videotape deck, as shown at near right, that can record programs off the air from a conventional TV set or be used with an accessory camera to tape live-action family scenes at home. Tape decks look much like standard reel-to-reel audio tape recorders, but are a little heavier and bulkier. Craig model 6401 (A) weighs 65 pounds, features a slanted supply reel that puts the tape in line with the helical-scan drum, eliminating the need for a step-down idler. Deck alone sells for \$850. Separate camera and TV monitor are available for \$248 and \$197 respectively. Concord model VTR-900 (B) has handy pushbutton controls, plays back through any TV receiver, is priced at \$995. Panasonic model NV-8100 (C) also has pushbuttons and features a detachable cover that closes the machine for use as a portable. Price for deck alone is \$1100. Ampex model VR-5100 (D) records for one hour, but has fast forward or rewind time of four minutes. Price is \$1600. Battery-powered Shibaden portable (E) weighs only 15 pounds, sells for \$1295. It records for 20 minutes in the field, but needs home tape deck for playback. Apeco mobile system (F) includes recorder, camera and monitor for \$1485, with stand extra



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24 PAGES

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MURDER OF THE ORIENT EXPRESS
The end of a great rail system

Americans seem to spend more time on home entertainment, and more time on the go, than any other nation. No wonder things which are self-powered portables are so popular these days.

You can get almost any kind of electronic entertainment powered by batteries: black-and-white or color television, stereo or mono cassette tape machines, and almost every radio band you can imagine—FM, AM, CB, TV sound, weather, public service, marine plus shortwave. And you can get these in almost any imaginable combination. The first choice you'll have to make in picking a portable for your summer listening is to decide just what kind of entertainment you want to take along. Radio? TV? Tape? A combination? Radio is sure to be available in any combination that you want. Radio-tape combos are common. There are a few radio-TV portables, and the only TV-tape combo due here is a JVC which includes a radio. Radio will be most people's first choice anyway. It's compact, inexpensive, drains batteries less than tape or TV, gives a wide choice of programs, works even far from stations, and usually is your best source of warnings about weather or other problems. If you have decided to get a radio, straight or in combination, you'll have to decide just what bands you want it to cover. *AM*, of course, carries great distances so you can pick up broadcasts almost anywhere you go. *FM* gives you less static and better listening, especially for music. *Weather band* broadcasts are very useful on vacation. *CB* and *public service* bands can be fun to listen to, and sometimes useful, but, since transmissions are brief,

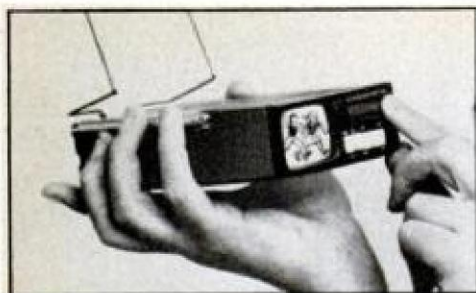
Take-along entertainment you can carry in your hand

TV, tape, radio—it's all portable, today.

by Ivan Berger



TV really is portable today. This Panasonic TR-555 weighs only 9¼ pounds, runs on D cells or your car battery and costs just \$150. The picture on the screen and those on the next two pages are real, right off the air. Today you can get most any electronic entertainment in battery-power form: TV, stereo, tape and all different sorts of radios, including FM, AM, CB, TV-sound, weather, public service, marine or shortwave. And you don't even need a long extension cord.



Pocket TV weighs 1½ pounds; is smaller than a paperback book; has a two-inch screen. Sinclair Radionics Inc., \$300.

it may be hard to catch something to hear. A scanner, such as GE's "Searcher" comes in handy if you'll be listening a lot to these bands, get a radio with a squelch control to cut out the bursts from static between transmissions. *Marine* band radio reception is handy if you're in a boat, and interesting if you're near a waterway (squelch helps here, too).

And *shortwave* is a story in itself. Shortwave broadcasts are common everywhere around the world. You can hear international SW broadcasting, plus the conversations of local and foreign "ham" operators. A lot of radios and radio/tape combinations have shortwave.

But many of the less expensive ones try to cram many of the shortwave bands into one band on the dial. That makes stations hard to tune, but still lets you pick up some stations.

If you're serious about shortwave listening, you'll want a radio that divides the SW spectrum into as many bands as possible, preferably with an added band-spread fine-tuning knob, and a BFO for tuning single-side-band and Morse (CW) broadcasts.

Music you pick yourself

Tape's advantages are somewhat different. With tape, you can take along your favorite music, rather than taking the long chance that some local station just might be playing it when the mood hits you. You can record sonic souvenirs of your vacation, possibly using them as a sound track to your movie or slide shows. And if your tape machine has a radio built in (as most do, if they're big enough for really good sound), you can also tape off the air. Sharp even has a model that lets you listen to AM while you tape FM, or vice versa.

The disadvantages of tape are only that it does deplete the batteries faster than radio, and that if you just bring a few cassettes along, you may get good and sick of them by the time you're ready to go home. That's

another advantage of combination units—greater variety in what you hear.

The major decisions in picking portable cassettes are whether to get a stereo or mono unit, and if stereo whether to get one with detachable speakers, built-in stereo speakers, or a single, monophonic speaker. Stereo gives a more spacious sound (especially indoors); and if you record someone talking in noisy surroundings, or several people talking at one time, you'll find it easier to understand what's said if it's been taped in stereo. Those built-in stereo speakers *do* work, surprisingly enough; but separate speakers work a bit better, provided you're willing to carry them along.

Superscope adds a fresh wrinkle to the speakers that attach to their CRS-152 radio/tape combination: Microphones in each speaker housing, so you can spread the mikes farther apart than single-point stereo microphones will let you (in many taping situations, though, you'll still want to keep them close together).

Still another new idea in stereo taping is JVC's HM-200E, headphones with built-in microphones for

binaural rather than stereo recording. Binaural tapes give much more realistic sound perspective when you listen to them over headphones, than stereo recordings can through speakers or headphones.

Uher, by the way, adds still another bit of versatility to its 201, the smallest stereo-recording cassette portable: An optional bracket for your car feeds it power from the car's battery and also has a built-in amplifier to boost its output enough to drive your car's speakers loud enough to be heard over the noises of the road.

If you're buying a tape portable, try swinging it as it plays, to make sure that neither motion nor any conceivable position will make the tape's speed vary. And if you'll be using it on batteries a lot, look for one with automatic shutoff, so the batteries won't keep draining when you reach the tape's end.

TV or not TV

TV—especially color TV—is the biggest battery-drainer of them all. I found that the JVC 3050, for example, would still play well and indicate full battery charge on FM or AM long after its batteries drained to the point where switching to TV



PM photo: Benn Mitchell

Материал, защищенный авторским правом

would drag the battery meter down to an indication of half-charge. TV ties you more closely to a nearby station than radios do. But it's also the most popular entertainment medium, and the one the kids are most likely to cry for—and that's often reason enough to bring it along.

Your main TV decisions are screen size and whether or not to get color. The color question will probably get solved first: Small color sets are a lot more expensive than black-and-white ones, and even a bit more than medium-sized color sets since the most popular sizes are produced in larger quantities. If the cost is no problem, remember that extra

color circuits add weight and subtract battery life. But bear in mind that color makes the details in a tiny picture easier to tell apart.

Pocket TV

One of the hottest new take-alongs is the subteeny Pocket TV by Sinclair Radionics Inc. The British company is selling its new Microvision for \$300 which brings a two-inch diagonal screen in a set weighing 26 ounces and smaller than the average paperback book. It measures 4 inches wide, 6 inches front to back and 1½ inches thick. It is powered by four AA rechargeable batteries.

As home screens grow ever larger, sets small enough to be portable look increasingly inadequate. But, in practice, they're surprisingly pleasant to watch. The small screen makes everything look sharper and crisper, just as a wallet-sized photo often hides blurs and imperfections which a big enlargement would show all too painfully. And the picture quality of the small sets themselves is fine.

Most portable TVs will run for several hours on batteries. That life usually can be extended by plugging

the a.c. power cord into a nearby socket whenever possible or using car cigaret-lighter power cords that come in many such TV sets.

Built-in batteries

In addition, some sets such as JVC and Panasonic radio-TV combos have built-in charger circuits for nickel-cadmium batteries, which can be recharged to cut the cost of truly portable operation; plug them into the power line and, while you're watching, they recharge. Detachable, rechargeable battery packs are also available for many sets, such as the Sony Trinitron color set shown.

Whatever type of portable you're looking for, you'll find some models easier to carry than others. To check balance and handle shape, you'll have to heft the set in the store. Make sure it has its batteries in when you try that. ★ ★ ★

Intriguing portables are (1) Sony KV-5100 color TV, \$460; (2) Superscope CRS-1800, \$240, with FM, tape, built-in stereo speakers; (3) Sharp GF-6000, \$170, radio and tape with automatic program search on tape; (4) Panasonic TR-535, \$200, with radio, pop-up TV; (5) JVC 3050, \$200, smaller and lighter radio-TV. Radio-with-tape combinations are common but only a few radio-TV portables are available. Look over our self-powered entertainers, select the fun you want for the beach or mountains, and toss out your extension cord.



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and Dodge

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Stained-glass creations that flood your home with color are easier to make than you think. S.E. Sayles created the window hanging with the same techniques you'd use for a window. *Photo: George Ratkai*

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INTERNATIONAL EDITIONS: Australia, Caribbean, Mexico, Southern Hemisphere

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Slip into something more comfortable gives you 9 exciting vacation homes that are ready when you are. Page 68.

How the tall ships sail details the strange maneuvers needed to steer a hard-to-handle square rigger. Page 78.

Look what's coming down the pike lets you peek at Detroit's timetable for model introduction and retirement. Page 100.

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POPULAR MECHANICS IS PUBLISHED MONTHLY by the Hearst Corporation, 224 West 57th Street, New York, N.Y. 10019. U.S.A. Single copy for the United States and Canada, 75 cents. Subscription prices: United States and Possessions, \$7.00 for one year; \$13.00 for two years; \$18.00 for three years. Canada, add \$3.00 for each year. All other countries, add \$5.00 for each year. Second-class postage paid at New York, N.Y., and at additional mailing offices. Authorized as second-class mail by the Post Office Department, Ottawa, and for payment of postage in cash. Registered as second-class matter at the Post Office at Mexico D.F., Mexico, June 20, 1950. © 1976 by The Hearst Corporation. All rights reserved. Printed in U.S.A.

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VIKING
ENTERS
MARS
ORBIT

ORBITER
CONTINUES
IN ORBIT
AROUND
MARS

PARACHUTE
DEPLOYS
ABOUT
20,000 FEET

LANDER
AND
ORBITER
MODULES
SEPARATE

LANDER
BEGINS
DESCENT

LANDER
ENTERS
MARS
ATMOS-
PHERE
ABOUT
800,000
FEET

AEROSHELL
BELOW
LANDER
JETTISONS

PARACHUTE
JETTISONS
AND LANDER
ENGINES
IGNITE ABOUT
4000 FEET

The most far-out event to celebrate America's Bicentennial will take place not here on Earth but on Mars. If all goes as scheduled, on the Fourth of July the Viking Lander space probe will touch down on the "red planet" to dig up—literally—cosmic secrets.

Not since men first walked on the moon seven years ago has there been so much excitement about a space venture. The Mars project, scientists believe, is even more important for it will be the first landing of a robot in regions of the universe where men cannot yet go. Earlier spacecraft had come within 3400 miles of Mars to take pictures, but now, for the first time, Mars will actually be touched and probed by a machine designed to

(Please turn to page 134)

Amazing search for life on Mars

Early next month, after a 460-million-mile voyage through space, a strange mechanical creature will land on the big red planet to unlock the secret man has pondered for ages: Is there really life on Mars?

by Hans Fante



FROM ENTRY
TO TOUCHDOWN
ABOUT
8 MINUTES

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**Moscow's
microwaves:
How Reds
spy on us**

**Make
CB RADIO
pay off
this vacation**

**BRAND-NEW
MINI VANS
EXCLUSIVE
FIRST LOOK**

**AMERICAN
ORIGINALS:
Shaker
classics
from kits**

**Update
your car
with 4 electronic
kit additions**

**NEW ELECTRONIC
CAMERAS-Just
aim and shoot**

**OWNERS
REPORTS:
Bobcat and
Olds 98**

**Latest scuba
gear...best
small boats
...and more!**



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The illustration by Van Kaufman portrays three mini-vans—the Elite (top), scheduled for production, and the Fiat and Honda concepts.

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How they're watching us is a special article revealing the use of very sophisticated gear in the space-age spying game. Page 47.

What Detroit has learned from recalls tells what's been gained as automakers end their first 10 years under the recall program. Page 56.

Shaker furniture is available to you in kit form—as it has been for about 150 years. Page 98.

Your best bets in bargain boats gives you a rundown on what's available this year in low-cost small craft. Page 74.

How far have we come since the Centennial Exposition? An amazing number of inventions introduced in 1876 are very familiar today. Page 78.

Call them mini-vans is an advance view of the scaled-down vans and station wagons that are on the way to the production lines. Page 50.

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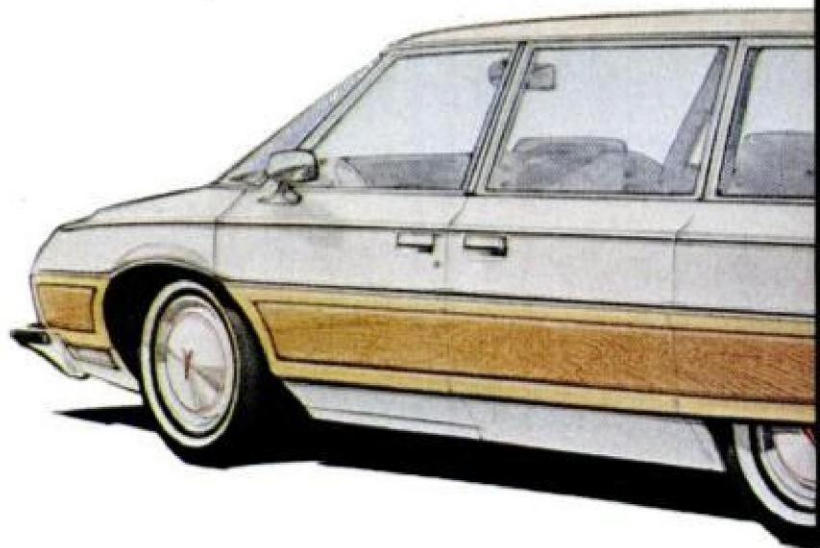
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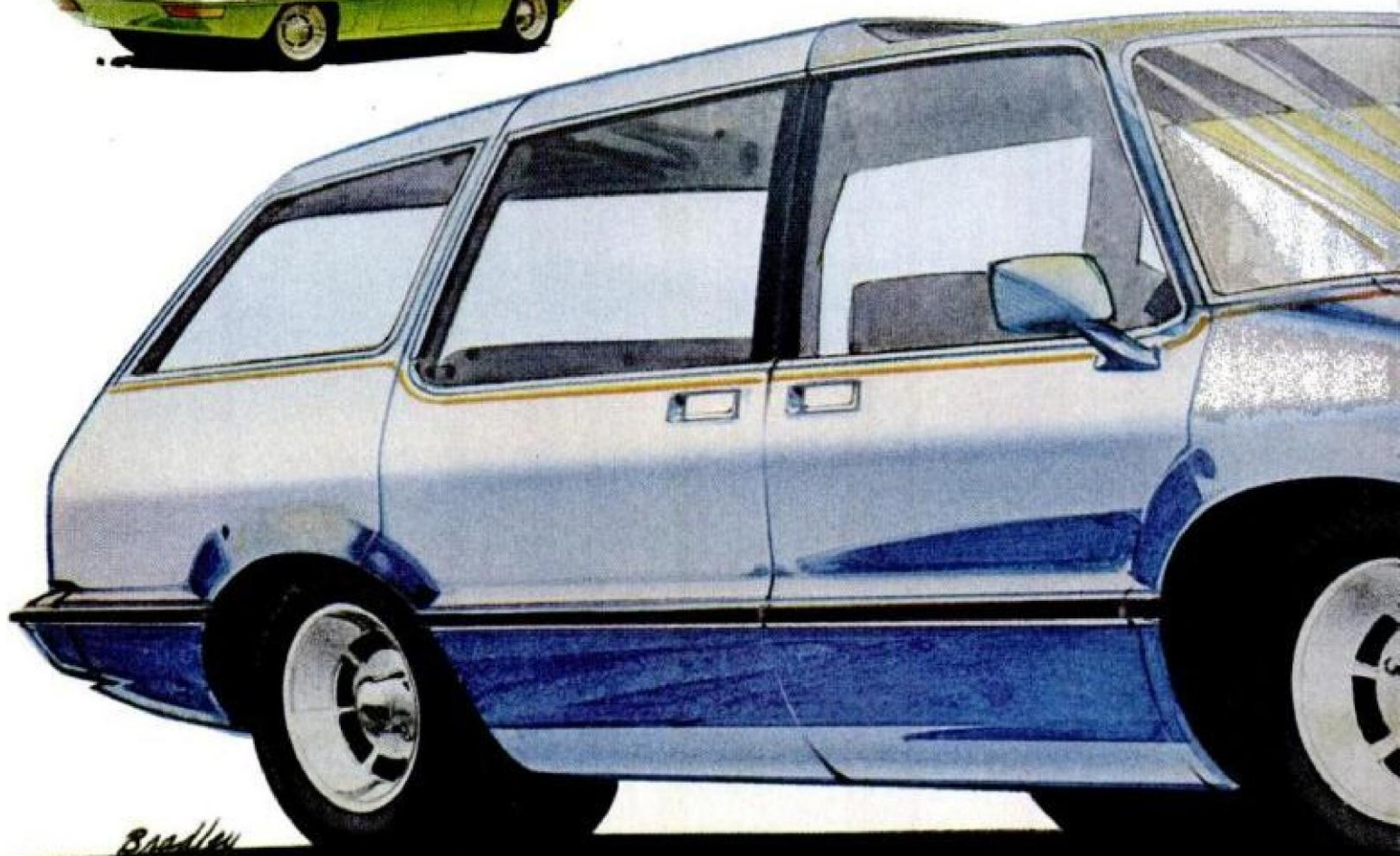
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Tiny Honda Life (above) uses Civic front-wheel-drive (fwd) running gear, is now sold in Japan, may appear in United States to cash in on van boom. Right: Elite's 49er Mini-Van stands but 49 inches tall; has gullwing doors, VW floorpan, engine. Below: Fiat's spacious Bertone six-door maximizes space places small-bore engine in rear.



Art: Harry Bradley



Bradley



GM's X-bodied wagon/vans were originally due with rotaries for 1977, but now will have Buick V6 and fwd. They will share major chassis components with that year's Nova-sized compacts; four GM divisions will likely offer them.



Toyota's cross between a van and wagon, the MP-1, stopped Tokyo Auto Show last year, uses Crown engine, but was initially intended for front drive.



Call them mini-vans

Some are scaled-down vans, others are more like station wagons, but they're all very practical and they're on the way to the production line.

With the van boom booming and no sign of abatement, Detroit and the importers are headed for a second generation of vans—smaller ones this time. These will come in addition to existing sizes.

The price of full-sized vans has doubled in the last five years, yet vans are selling at a brisker clip in this country than sports cars. If the car companies can bring prices down, they'll open up a whole new market segment. And mini-vans will not only cost less to buy; they'll be cheaper to drive, maintain and (in some states) license.

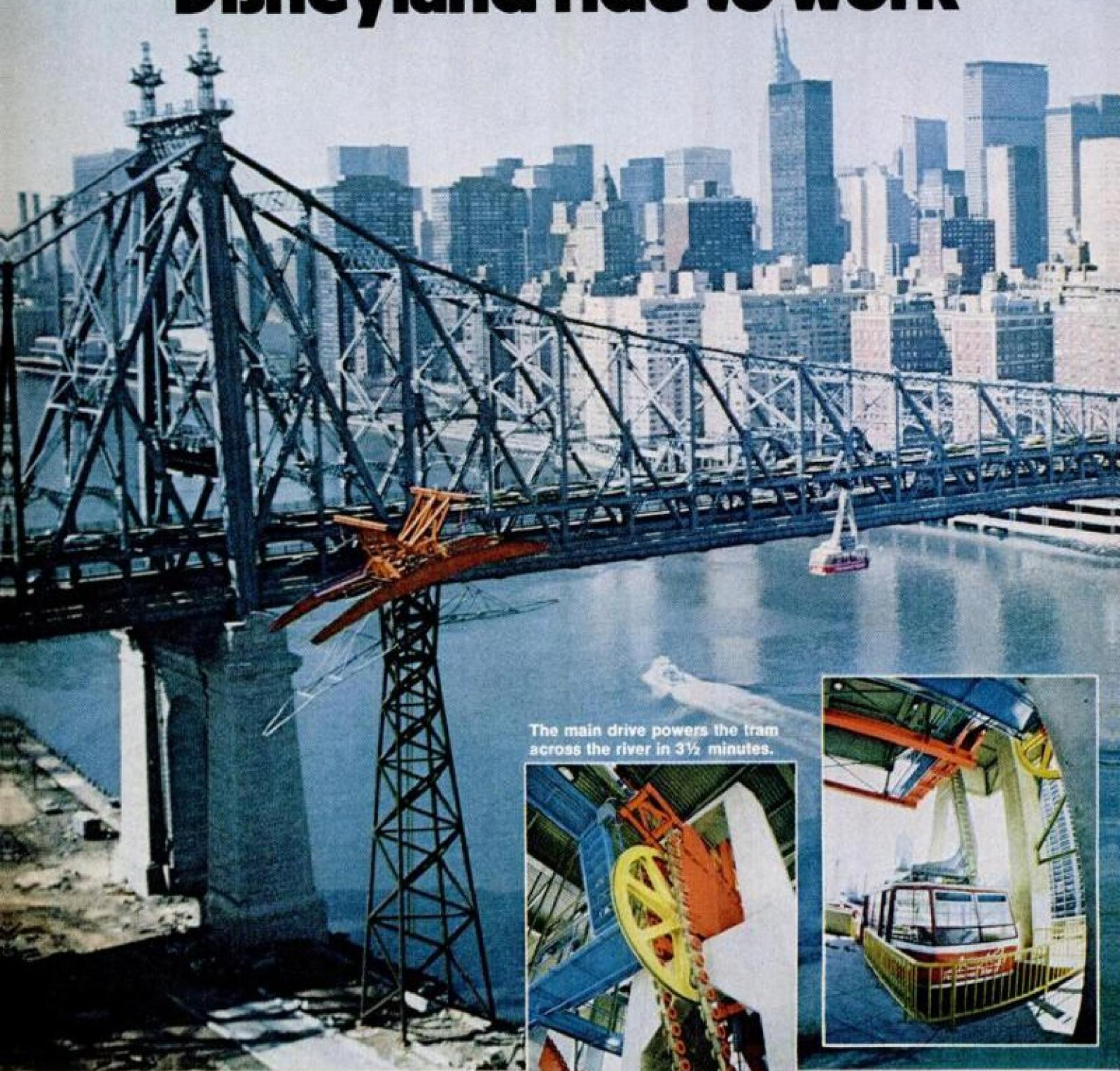
According to industry figures, today's average van owner is 22½ years old, recently married, and spends about \$850 a year buying van accessories. Van conversion outfits can't keep up with orders.

Detroit loves the van boom, and there's presently a battle royal between the Big 3: Ford, Chevy/GMC and Dodge/Plymouth. Van clubs and van meets have swept the country.

In Detroit, the first new small van will come from General Motors. GM plans to go with a front-wheel-drive (fwd), V6-powered compact mini-van on the 1978 X-body, which currently serves GM's N-O-V-A quartet (Nova, Ventura, Apol-

(Please turn to page 118)

Airborne commuters take a Disneyland ride to work



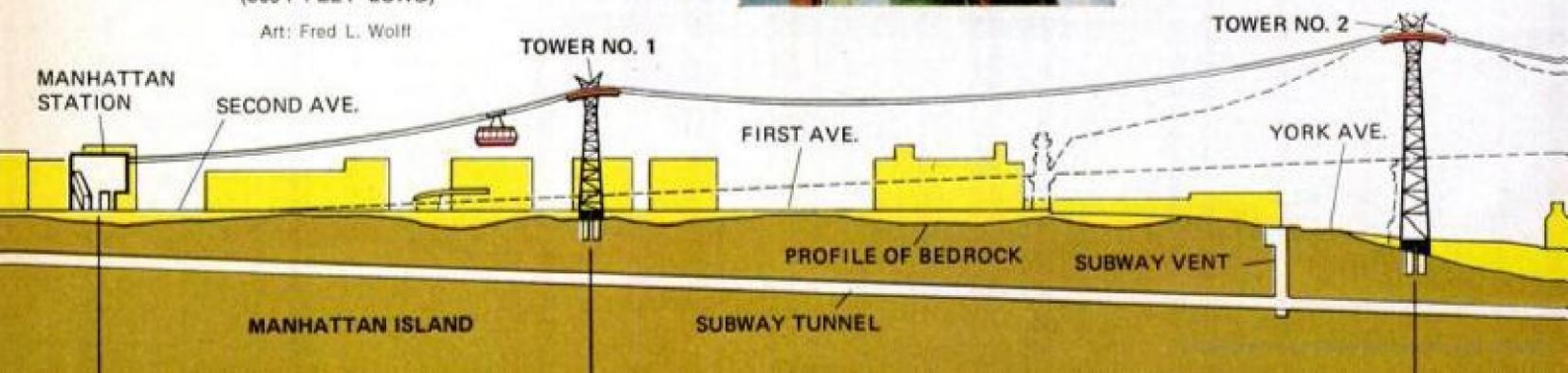
The main drive powers the tram across the river in 3½ minutes.



The gondolas settle into brightly painted stations for loading.

PROFILE OF TRAMWAY CIRCUIT (3094 FEET LONG)

Art: Fred L. Wolff



by Mike McClintock

ASSOCIATE HOME AND SHOP EDITOR

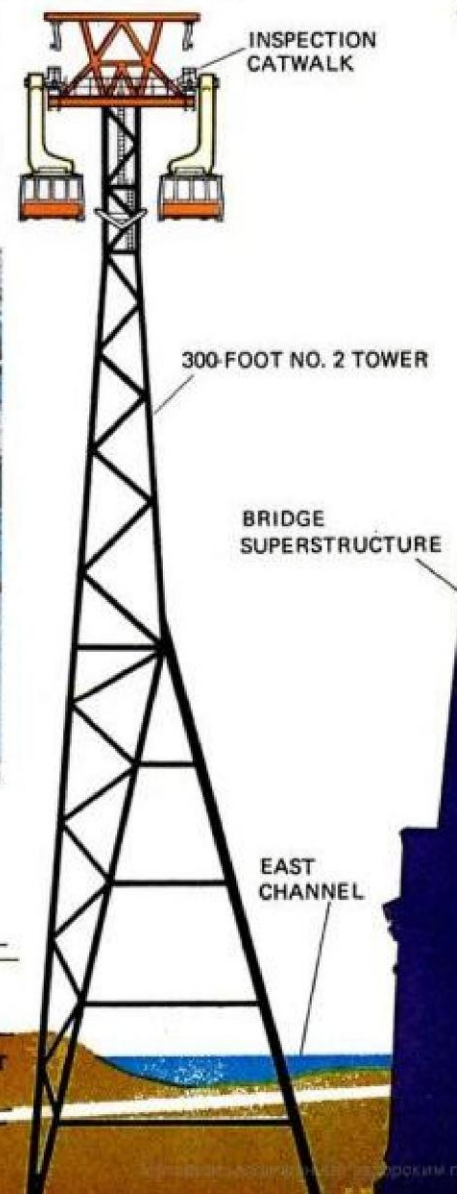
The world's first mass-transit tramway now carries commuters on a wonder ride between two islands in the heart of New York City—Roosevelt and Manhattan. In a spectacular 3½-minute skyride, travelers from Roosevelt Island in the East River literally fly by the city's horrendous rush-hour traffic, touching down in midtown Manhattan.

The tramway builder, the New York State Development Corp., hopes the unique facility will be a two-way street across the rushing river. It will serve those living in the corporation's newly built residential community on Roosevelt and those walled-in Manhattan apartment dwellers, who will have easy access to Roosevelt's recreational areas.

Passengers to and from the islands will travel in two synchronized gondolas (each holding 125 people) that load simultaneously at opposite ends of the circuit. Each cabin has an op-

(Please turn to page 112)

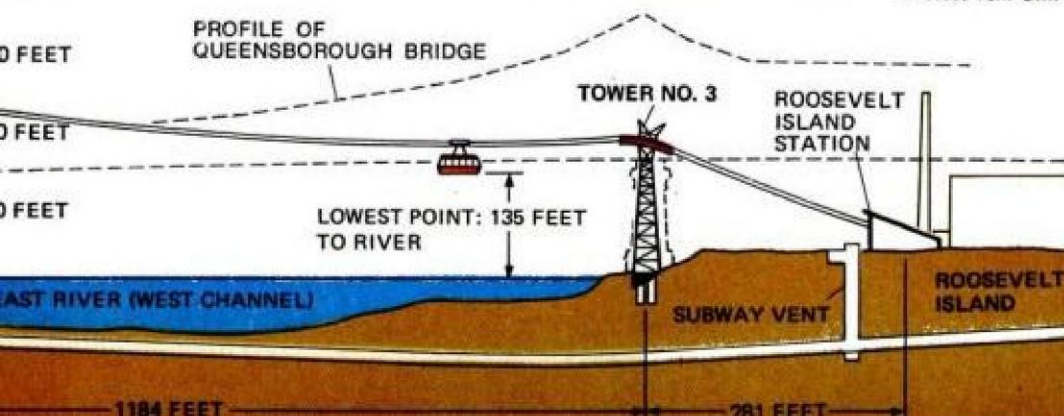
HEAD-ON VIEW, TOWER AND BRIDGE



Tramway riders will get a spectacular view as they beat the crush of rush-hour traffic.



Photos: Tom Grill



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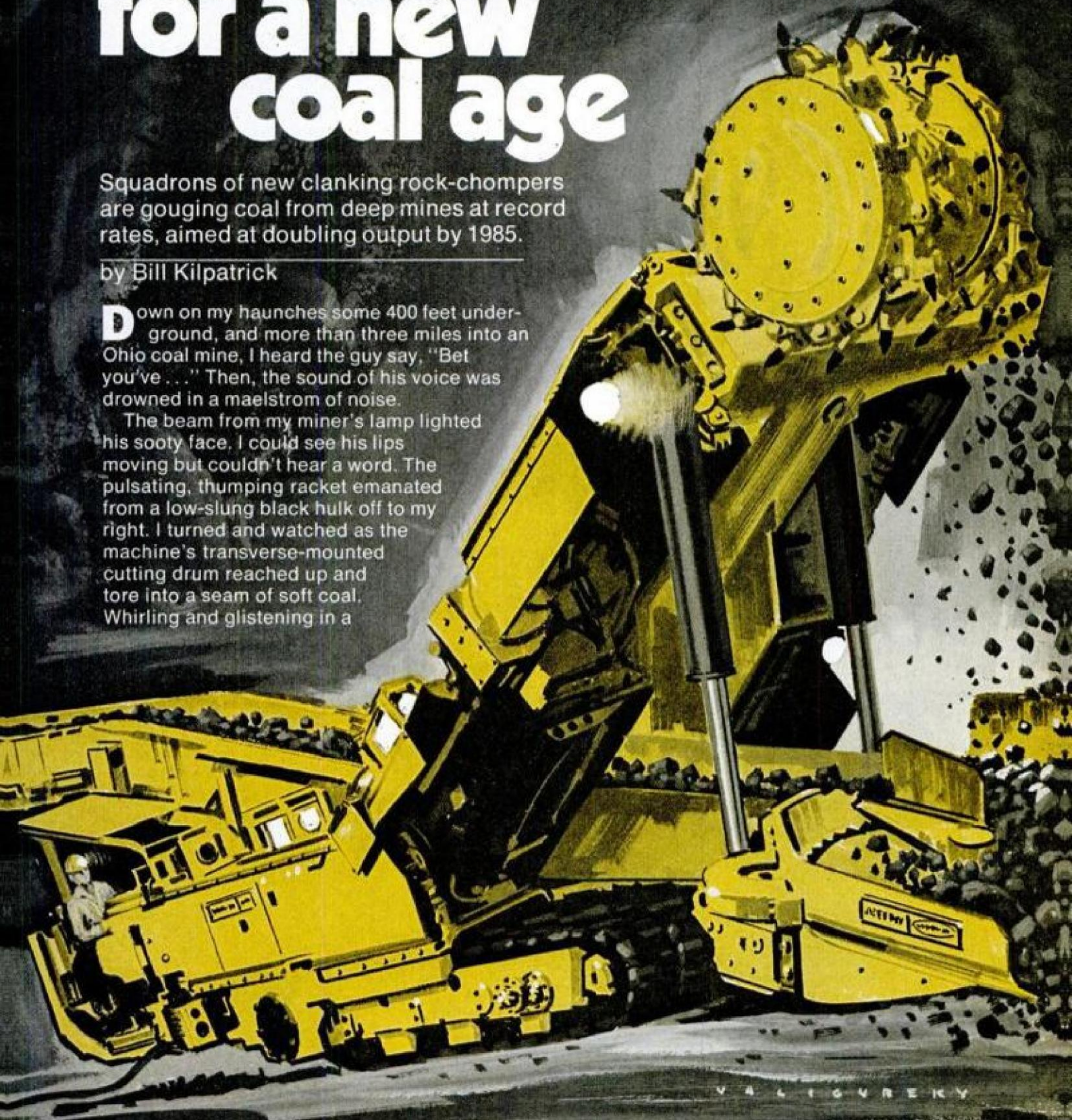
Giant miners for a new coal age

Squadrons of new clanking rock-chompers are gouging coal from deep mines at record rates, aimed at doubling output by 1985.

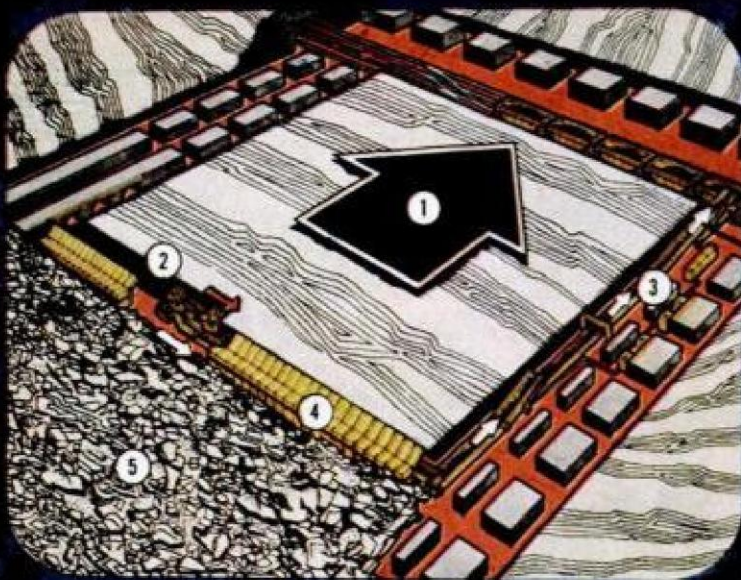
by Bill Kilpatrick

Down on my haunches some 400 feet underground, and more than three miles into an Ohio coal mine, I heard the guy say, "Bet you've . . ." Then, the sound of his voice was drowned in a maelstrom of noise.

The beam from my miner's lamp lighted his sooty face. I could see his lips moving but couldn't hear a word. The pulsating, thumping racket emanated from a low-slung black hulk off to my right. I turned and watched as the machine's transverse-mounted cutting drum reached up and tore into a seam of soft coal. Whirling and glistening in a

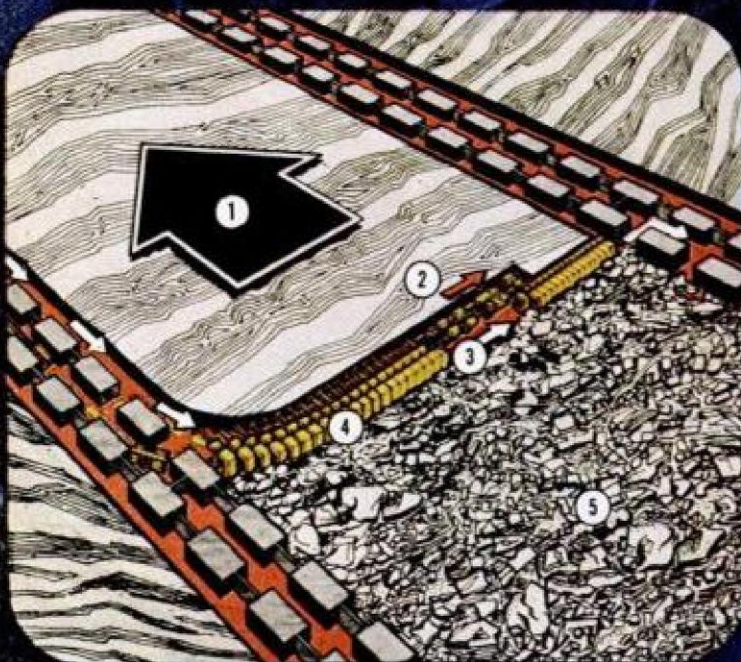


VALIGUREKY



LONGWALLING

Giant shearer moves back and forth along seam face in a corridor first opened by a continuous miner, which also carved tunnels for moving coal to surface. As machine and supports progress, ceiling collapses behind them as "gob." 1. Mining direction. 2. Shearer. 3. Conveyor. 4. Supports. 5. Gob.



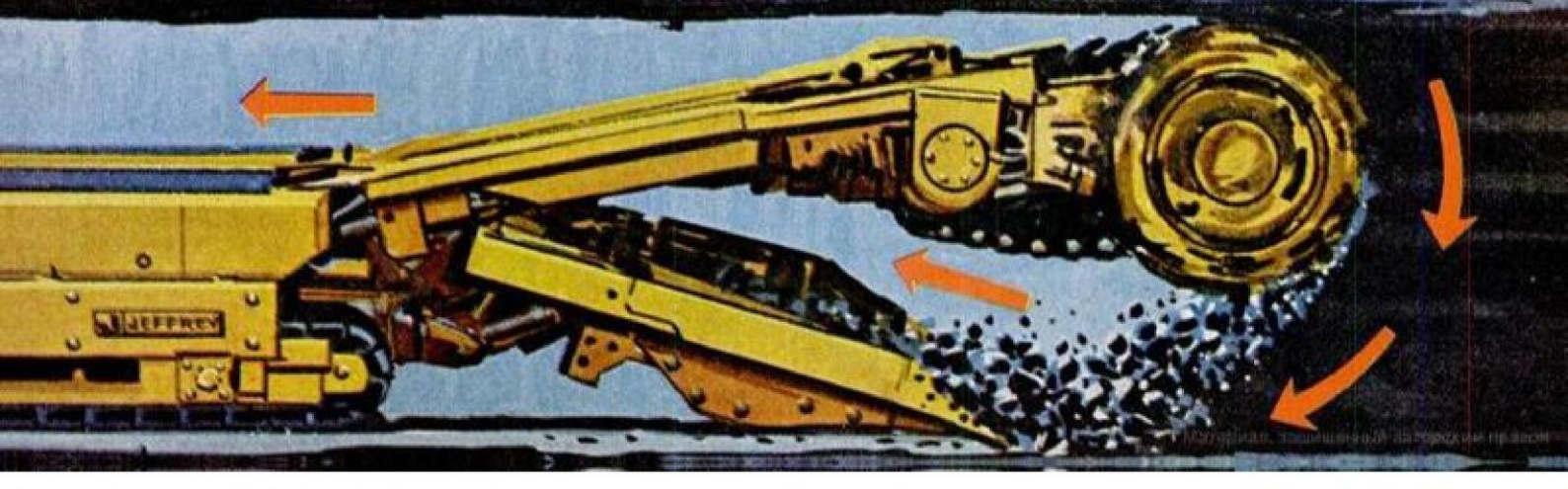
SHORTWALLING

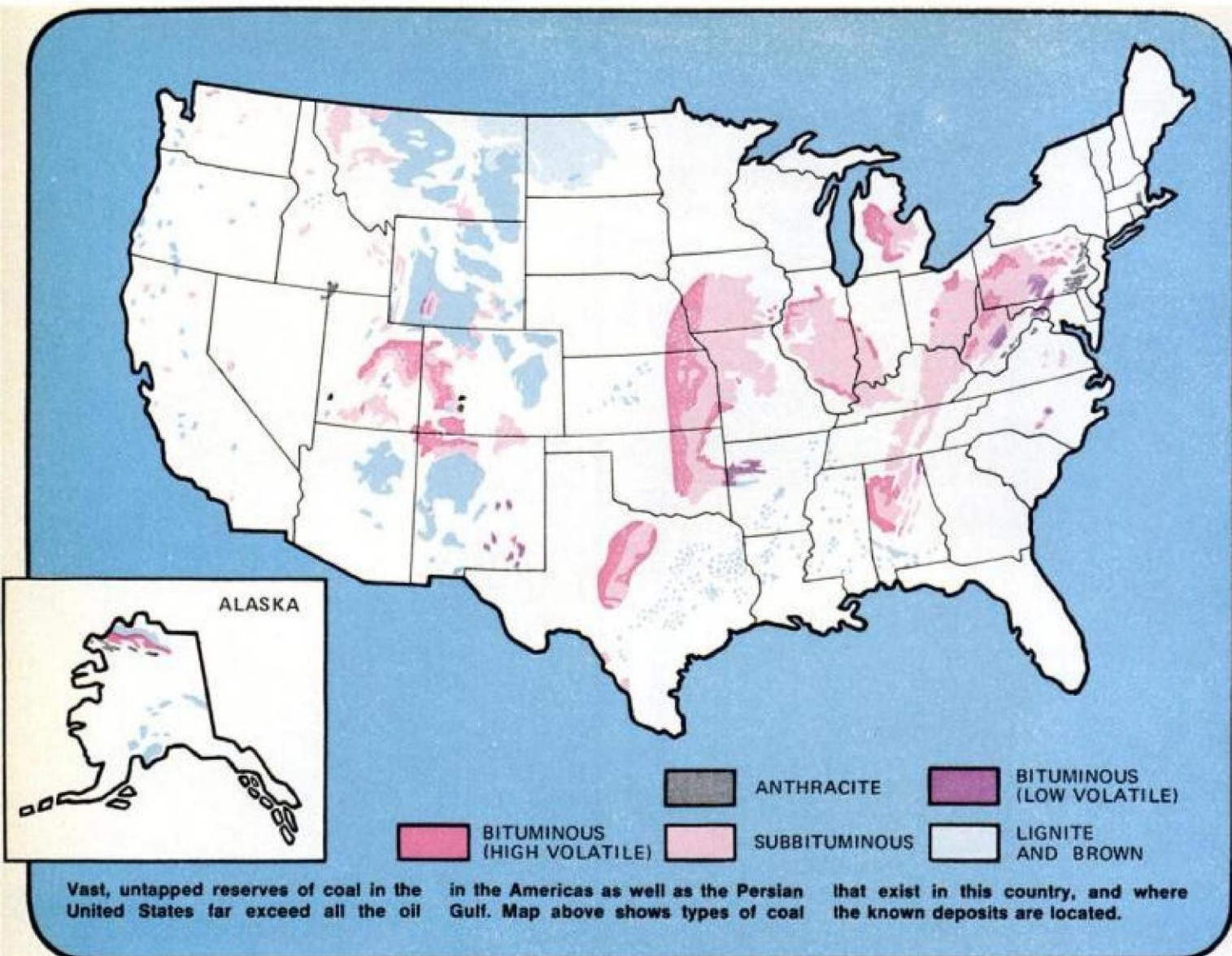
Low-slung continuous miner has rotating head that can reach to the ceiling of a thick seam. It grinds one way along face of seam, then backs off for another go. Again, the ceiling collapses behind it as hydraulic roof supports ram forward. 1. Mining direction. 2. Miner. 3. Conveyor. 4. Supports. 5. Gob.





Gigantic horizontal auger on Bunyanesque hydraulic arm of longwall miner (above) can crumble 12,000 tons a day from face. Continuous miner (below) though limited to forward travel, can burrow into deposits.





water spray to hold down dust, the drum's spiraling row of tungsten-carbide teeth raked the face of coal from top to bottom. The ripped-down stuff cascaded to a moving belt and was conveyed along the machine's back and off its rear end onto the bed of a waiting and equally low-slung shuttle car.

The noise stopped as abruptly as it had begun. The loaded shuttle car pulled away with a muffled rumble and disappeared in the darkness. From start-up to shutdown, the entire process had taken little more than 30 seconds.

"Really something, isn't it?" the fellow hollered, moving closer. "Bet you've never seen anything like it."

He was right. To me, as perhaps to most people, the underground mining of coal was a vaguely realized, unworldly business involving exploited, dirty-faced men wielding picks and shovels, spavined mules lugging overloaded tram cars, and caged canaries destined to keel over dead when the concentration of gas in the air approached lethal density. But this incredible machine—less

than 30 inches in height and not much wider than a standard car—that zapped through coal like it was butter, was a long way from my antique concepts.

Continuous miner

"It's called a continuous miner," my companion said. "It cost about \$300,000, and the man operating it gets \$63 a day, so it isn't exactly a nickel-and-dime setup. A number of companies make them, but that particular one's a Jeffrey 120. It weighs better than 77,000 pounds

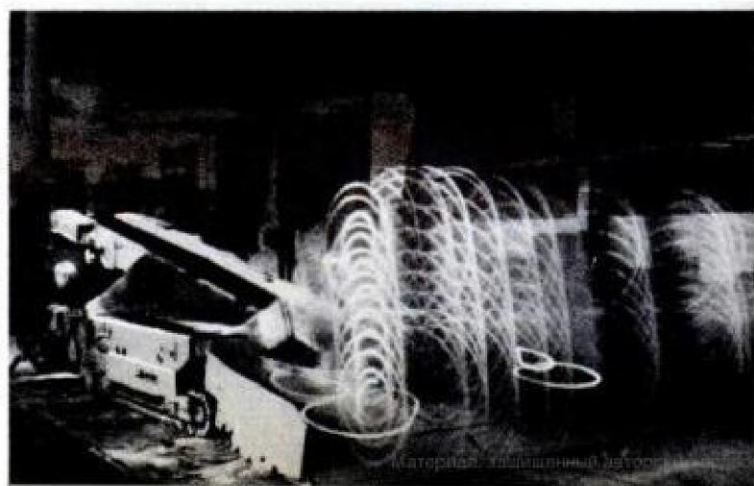
and it's powered by a couple of 225-hp electric motors. That big cable you see trailing back next to the water hose is hooked up to a power distribution center farther back in the mine.

"All this equipment down here runs on electricity. It comes in from up top. We mine the coal that gets sold to the power company to generate the juice we have to buy to mine the coal."

"How much coal did that machine just rip down?"

"About five or six tons," he said.

Head-on time exposure of a continuous miner in action on coal face illustrates the auger-like action of the big spiraling cutter head when it chews its way into the solid material at the working front of a soft coal deep mine.



"Hell, it'll chew it out of here better than ten, maybe twelve tons a minute."

Some quick figuring, and that added up to a production potential of more than 5000 tons per eight-hour shift; 15,000 tons a day!

The machine I'd been watching is one of several types of Bunyanesque monsters that will be gouging into our vast coal reserves to meet soaring quotas as gas and oil supplies dwindle. Newest, and even more formidable than the continuous miner is the "longwaller"—a roaring giant with a side-winding auger some six-to-eight feet in diameter, known as a "shearer." This unit rumbles back and forth along the face of the coal seam, its whirling, toothed auger slicing a couple of feet off the face at every pass. As the machine progresses into the deposit, a long row of hydraulic roof supports pulls itself along behind it, allowing the mine roof to collapse into the mined-out area.

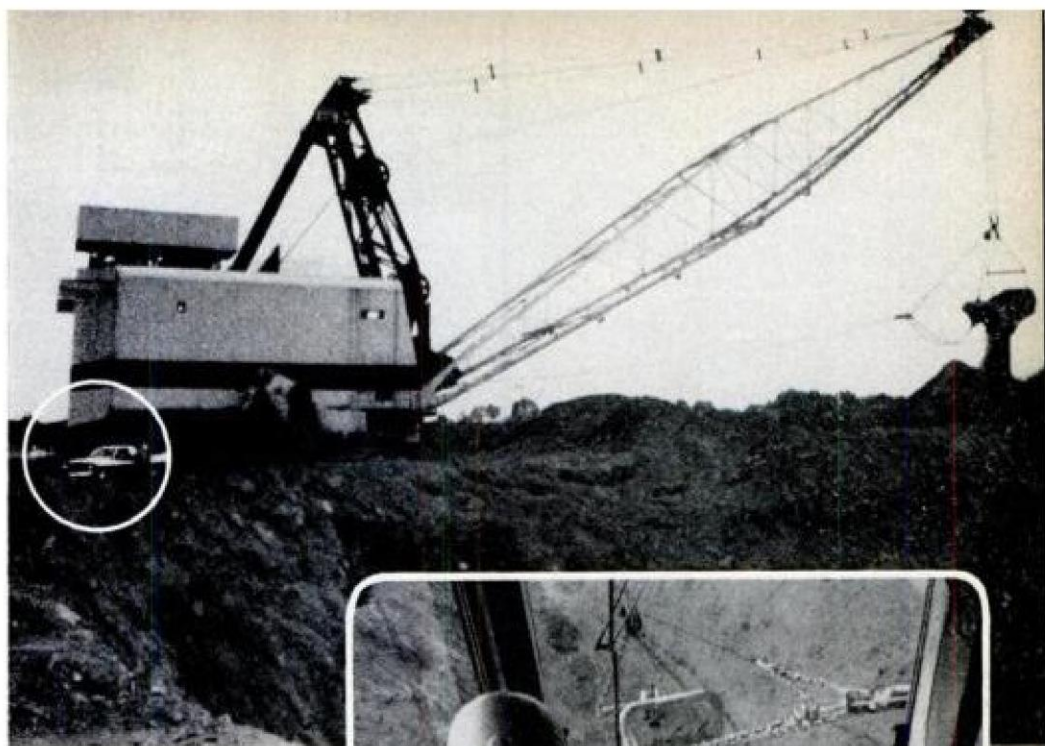
10-story 'walking' draglines

Gargantuas of the mining business, of course, are the 10-story-high "walking" draglines with scoops big enough to swallow a three-bedroom house and attached garage. The biggest can scoop up to 200 cubic yards of overburden at a single pass (the average 10-wheel dump truck that carts fill from construction sites holds about 12 yards). Armies of such draglines already are at work opening the yawning canyons of our burgeoning strip mines.

More about all these fantastic machines presently. Together, they form the clanking, roaring, humming battalions of weaponry that will help us embark on our second coal age—a renaissance that, in terms of tons produced, will make the last one seem like kids on a beach with tin shovels and pails. President Carter has called for coal output to nearly double—to 1.2 million tons a year—by 1985.

Coal comprises 90 percent of our total fossil fuel reserves—a resource far richer than all the known oil in Alaska, the Persian Gulf, the North Sea and Latin America combined. The President's goal would bring coal's share of our total energy needs to about 29 percent, and cut back our need for foreign oil to the 15 percent we imported back in 1973 when the Arab oil embargo went into effect. Without that boost in coal output, we'll be up to 60 percent oil imports by 1985.

It will take a heroic effort to achieve that 535-million-tons-a-year increase in nine years. Are the ma-



More than half the bituminous (soft) coal now mined in this country is strip-mined. Colossal "walking" draglines like this—with housings as big as a 10-story office building—scoop 200 cubic yards at a bite to clear overburden from the 150-foot-deep canyons they dig to expose coal.



chines heroic enough to make it? Very likely, even with their limitations.

Shuttle-car bottleneck

Actually, that 15,000-tons-a-day potential I'd calculated off the top of my head for the continuous miner doesn't happen in day-to-day operations. My companion in the mine noted that the term "continuous miner" is misleading. "It can't mine coal more than two hours each shift," he informed me. "Mostly, it has to wait on the shuttle cars. They haul about six tons each trip. There's only room for so many, and they can go only so fast back and forth between loading up here at the face and unloading at the nearest conveyor. If nothing breaks down, we can get 500 tons or so out of here each shift."

"What does a ton of this coal sell for?"

"Well," he said, "that depends on the contract with the individual customer, and on how far and how difficult it is to get the coal to where the customer wants it. In general this kind of coal retails for about \$18, maybe \$20 a ton."

"How much of that is profit to the coal company?"

"You got me," he said. "There are a lot of variables in pricing coal. I've heard some fellows say the company's making \$5 a ton, and others say the profit on a ton of coal isn't

much more than a couple of bucks. Look, here comes the other car."

I watched as the double-ended shuttle car slipped out of the darkness into the dancing light of the work crew's lamps. The semiprone operator eased it up under the continuous miner's conveyor, and again the rhythmic thumping and grinding racket drowned out all conversation.

Despite the production bottleneck caused by the need to utilize shuttle cars in most deep mines, continuous miners will rip out well over 60 percent of the approximately 280 million tons of bituminous (soft) coal to be mined underground in the United States this year. Such machines, of which the Bureau of Mines estimates some 2500 to be in use, represent by far the most commonly used method of deep-mining soft coal.

The traditional method of mining both soft and anthracite (high-carbon hard coal used mainly and, these days rarely, in home heating) consists of cutting out big blocks with mammoth chain saws, then drilling and blasting the blocks into loadable chunks. The method, still widely used, accounts for over 30 percent of America's annual bituminous production from underground mines. And, despite widespread mechanization of deep mining over the past century, a few million tons of coal

(Please turn to page 136)

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Published by Popular Mechanics Company, RICHARD E. BERLIN, *President*

DON DINWIDDIE
Editor

RICHARD E. DEEMS
Executive Vice-President

JOSEPH R. BUELL, JR.
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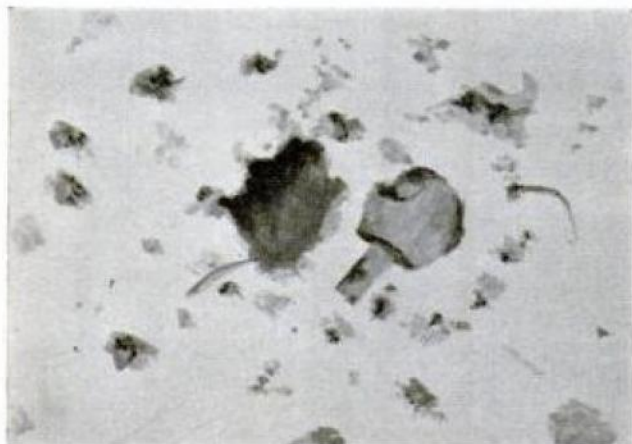
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UNKNOWN MENACE:

Germs from Outer Space



METEORITE FOSSILS (left) show striking resemblance to germs found on earth (above, right). Are they space germs? If so, spaceships will have to be equipped with germlocks to decontaminate spacemen (right)

By Theodore Berland

JETS WHINING, the shiny airliner settled smoothly on the runway at Washington National Airport near the nation's capital. It swung onto a taxi strip and stopped. A battery of trucks swarmed out to meet it.

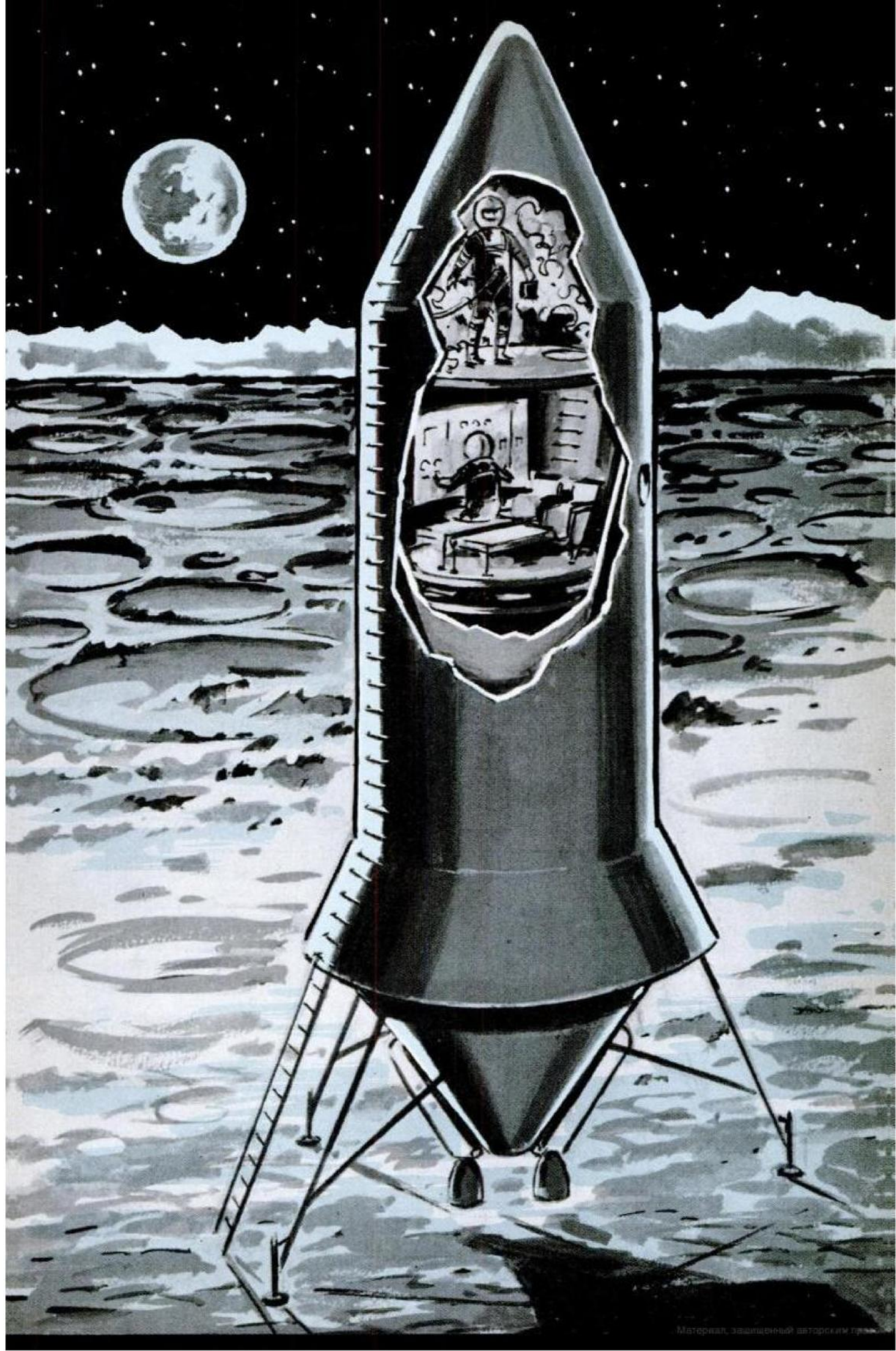
Inside the cockpit, the sweating pilots worried about their deadly stowaway. Pink fluid alive with poliovirus had leaked from a two-quart jug being shipped from a Detroit vaccine maker to researchers at Johns Hopkins University at Baltimore.

The crew and passengers fled from the plane's emergency exits. (All were later given Salk shots and had their baggage scrubbed with alcohol.) Then a team of strangely-dressed Army chemists and technicians stepped into the plane and pumped a sweet-smelling but deadly gas called ethylene oxide into the cabin.

Within hours, all of the fugitive germs were dead. The next day, the DC-4 was back in service. A major epidemic in the nation's capital and on the airlines had been averted.

This incident—which actually happened—had a happy ending. So did the invasion of germ-carrying Martians in Orson Welles' infamous radio rendition of H. G. Wells' "The War of The Worlds," which panicked several million 1938 listeners who thought it was a factual news report. Wells' work was fiction, fortunately.

Both of these seemingly unrelated incidents may, however, have an ominous—and very real—space-age sequel. What will happen when expeditions from earth go to the moon or Mars and come back with as yet unknown germs from other planets? Such germs could cling to the spacecraft or



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SMARTER AND
CHEAPER
(\$16⁹⁵ up)**

**How to choose one
for home, school
or business**

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build a colonial pine
trestle table and
benches for \$70**

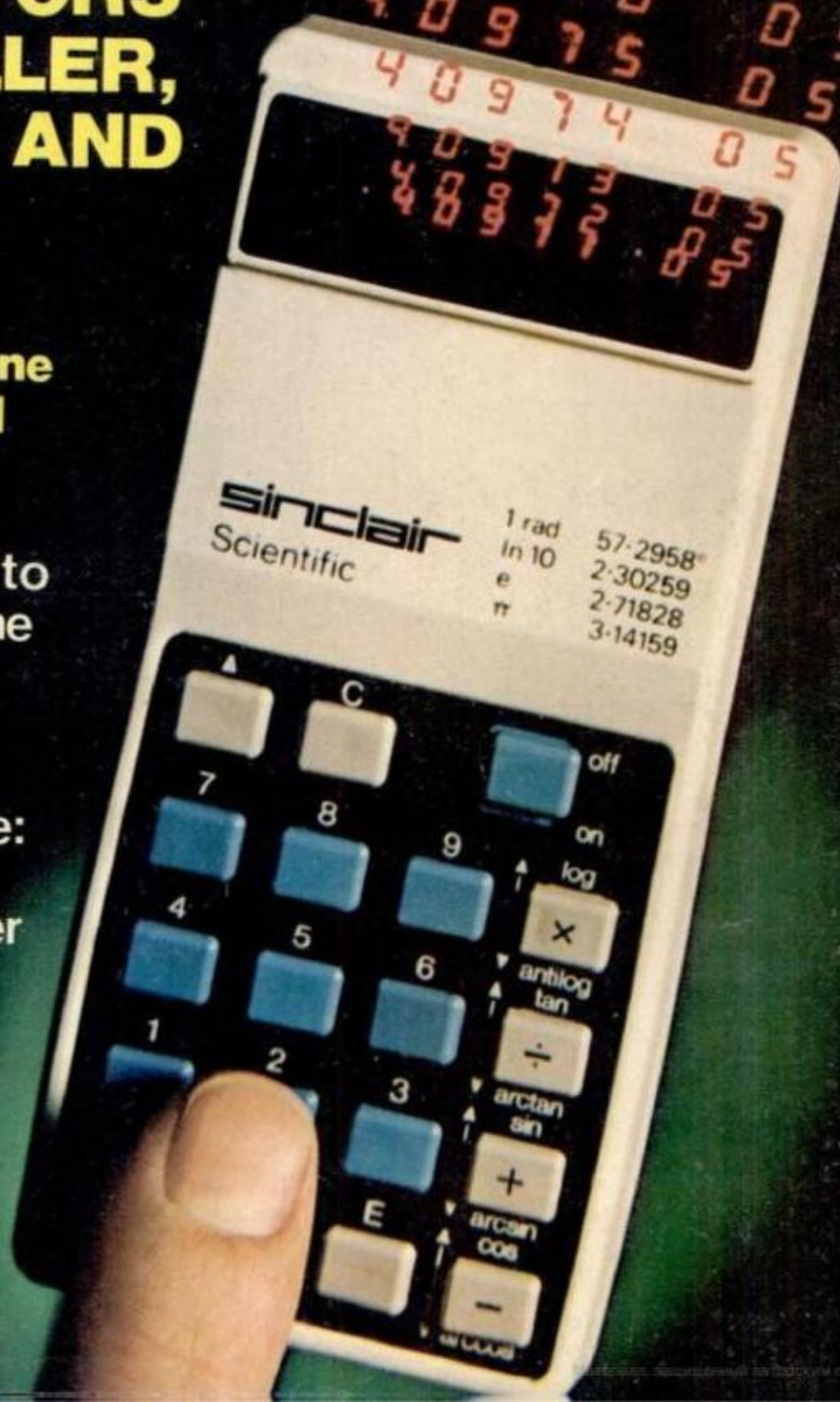
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- Toy racetrack
- Lazy Susan server
- Wine rack
- Cutting board
- Artist's sketch bench

**Trucks: How
they've solved the
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ON THE COVER: Calculators get smaller, smarter and cheaper. But just how did the photographer, Ben Rose, manage to get all those numbers to leap right out the window? A laser helped. See *Photo hints*, page 38.

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Calculators get smaller, smarter and cheaper

Here's how to pick the right one.

by Ivan Berger
ELECTRONICS EDITOR

Plug for a.c. power supply means longer battery life

Enough digits?
Six are minimum,
eight are handier

Floating decimal makes calculation more flexible. Two-place decimal is okay for dollars and cents

Can digits be read easily in hand? On desk? Decide position in which you'll most often use calculator

Switch must be hard to push "on," preventing accidental battery drain

Separate "clear" and "clear entry" keys simplify long calculations

Decimal key is a must

Key "feel" must be positive, so you can tell without looking whether entry is completed



Everything else may be going up in price, but calculators aren't—they're coming down, dramatically. Hand-held calculators, news when they first appeared for about \$400 each, have now come down to \$16.95, with rumors flying of \$10 calculators to come.

That's probably rock-bottom, though. The emphasis already has switched from how inexpensively a calculator can be made to how well and conveniently it can be made to work and still sell at a moderate price, and in the smallest package that will still leave room to push its keys. Though wrist-watch-size calculators (which have been designed and could be built today) are probably too small to be really practical, today's smallest can be very small indeed, yet still pack a lot of calculating power.

The Sinclair Scientific on our cover is a prime example. For just \$69.95, it does trigonometric and logarithmic calculations as well as the usual four calculator functions (addition, subtraction, multiplication and division) all in a package just $4\frac{1}{2}$ by 2 by $1\frac{1}{16}$ inches (shown one-third larger on our cover). That's just about everything you could get in a \$30 slide rule, with a lot more accuracy (to five significant figures) and a lot handier size. If you don't need a slide rule, you can get a four-function, eight-digit Sinclair the same size, for just \$40—assembled or in kit form (see photo on page 72).

But just how much calculating power, and how many (and which) features do you need—and do you need a calculator in the first place?

At today's prices, if you do enough arithmetic each month to grumble about (or enough to make occasional mistakes) you can probably both use and afford a calculator—to help you check prices and unit costs when shopping, keep your checkbook straight, or check your bills for accuracy. For the rock-bottom minimum of calculation, something like the \$16.95 Novus will probably do fine. Its decimal point is present at two places, for dollar-and-cents figuring, and its six-digit display lets you add, subtract, multiply or divide up to \$9999.99—probably more than you usually keep in your checking account.

But if you use it at all regularly, you may find yourself hankering for some of the

additional basic conveniences found on calculators like the Panasonic 883 at left. Having a *decimal key*, for instance, means you don't have to enter the zeros for round numbers of dollars, and lets you multiply decimals (when figuring percentages, for instance) without having to keep track in your head of where the decimal point should wind up in the final result.

Floating decimals, now found on most hand-held calculators, show exactly as many digits after the decimal point as there are significant figures to display—no trailing, final zeros. Floating decimals are versatile, adapting themselves automatically to each calculation for maximum accuracy; but since having no fixed decimal-point position can make fixed-decimal calculations like dollars and cents harder to read, some calculators offer preset decimal settings as well. Common settings include two-place (for dollar-and-cent addition and subtraction), three-place (dollar-and-cent multi-



Cheapest calculator—at least as we go to press—is this \$16.95 Novus 650 Mathbox, which lacks some desirable features, such as a decimal-point key.

plication and division, with the extra digit helping you round off correctly) and five places (where you need high, but not overbearing, accuracy). A few calculators will *round off* figures, raising the last digit by one if the next digit would have been five or over, but most just cut off any figures that won't fit their displays.

In the latter case, most calculators *underflow*, displaying the highest, most significant digits, and dropping off the less significant digits at the right of the figure (usually with some indication that the answer shown is not complete and of how

All the basics are shown on Panasonic's \$70 Model 883 (left). But similar Panasonic 840, now available, is smaller, costs only \$50.

many digits have been dropped before the decimal point). This indication varies from machine to machine, though: Of the three typical calculators we tested, one blinks, one displays apostrophes (easily overlooked, alas), and one has an overflow key (a rather uncommon feature) that shows you any remaining digits when it's pushed.

A calculator's *display* must be big enough for you to see at a convenient working distance, and must be visible from whatever viewing angle you'll be using: straight up for hand-held use, at about a 45° angle for use on a desk. The Sinclair Cambridge (below) and Scientific, for instance, are very convenient for hand-held use (you can hold and operate them with the same hand), but their narrow viewing angles make them

awkward on a desk. On the other hand, because the Casio's display is set to one side of its keyboard rather than above, it becomes most convenient for desk use and quite inconvenient when hand-held, even though its display angle is wide enough for any use.

Credit balance, a minus sign in front of negative results, is now almost universal (some earlier calculators would show the result of four minus five as a string of nines, rather than -1). But some minus signs are easier to read than others: Of the calculators shown on these pages, for instance, the Panasonic shows it as a red dot below and to the extreme left of the display, the Kings Point shows it as a minus sign at the far left, and only the Sinclair



Sinclair Cambridge comes assembled or in this three-hour kit (not for beginners) for \$40. Size is identical to Sinclair Scientific (shown oversize on cover).

Extra features handy for most home calculations are shown in the Casio \$40 Mini Memory (right), found in many other common calculators as well.



"T" setting on this Casio's on-off switch controls memory. Most calculators with memory use a separate switch

and Casio show it clearly as a minus sign immediately before the figure.

The displays consume most of the power in the average calculator, far more than do the transistors that perform the calculations. Some calculators are therefore coming out with less power-hungry, liquid-crystal displays, whose digits darken or turn silvery instead of lighting up. These are easier to read in bright light, too, not "washing out" as self-illuminated displays do—but in dim light, they're much harder to see, and some users have trouble seeing them from all but a few angles. So if you're interested in liquid crystal display for longer battery life try it under typical indoor illumination before buying it.

Batteries are very important, of course,

in your selection of any portable device. If you'll be using your calculator in one place all the time, or for several hours each place you use it, you might prefer an a.c.-operated, desktop model that must be plugged in to operate, but offers the advantage of a larger display and more comfortably-spaced keys. If you frequently use your calculator in one place, but do need to use it portably from time to time, a hand-held model with rechargeable battery is probably your best bet. If you travel a lot, running the risk of leaving your recharger home, you're safest with a model whose batteries can be replaced when dead, especially if they're easy-to-find types such as 9-volt "transistor" batteries, or AA "penlight" cells (smaller AAA batteries, or

Memory ("M" on most machines, "T" on this one) stores intermediate totals, constants, for later use

Percentage key eliminates decimal confusion when figuring percentages

Overflow key allows 16-digit result on 8-digit calculator, shows 8 digits at a time; it's handy, but uncommon



hearing-aid-type mercury cells are harder to find). Even the disposable-battery types, though, often have sockets for optional power supplies, so you can conserve battery life by running them from your a.c. house current or off your car's battery whenever possible.

The keyboard is important, too. The keys themselves should fit your fingers, feel good, and give you some sort of tactile indication that you've pressed the key in far enough to complete entry. We're partial to keyboards that "click" when pressed, but we've heard that some may click without registering if you press the side rather than the top of the key; check all the keys for that before you buy. Check, too, that no keys stick, and that the calculator won't register a number twice if you accidentally tap the key so fast its contacts bounce. Keys should

also be big enough to hit easily, and far enough apart to minimize the chance you'll hit the wrong one.

A look at the keyboard will also tell you whether it uses *algebraic* or *arithmetic entry*. Algebraic keyboards, with separate keys for $+$, $-$, and $=$, let you key in additions and subtractions exactly as you'd write them down. Arithmetic keyboards, recognizable by their $+=$ and $-=$ keys, require a slightly different key sequence: you push $+=$ after all positive numbers, $-=$ after all negative numbers or numbers to be subtracted (multiplication and division are the same for both key systems). Though the algebraic system is more natural, most people, we find, can pick up the arithmetic system in no time flat. The only problem occurs when you're switching between calculators; so if you're buying more

Scientific calculators are specialized tools, but their prices are coming down into the consumer brackets.

This Kings Point SC-40 is \$150; Sinclair Scientific on cover is less versatile, but is only \$69.95.

Radian/degree conversion switch. If you don't know what radians are, you don't need it

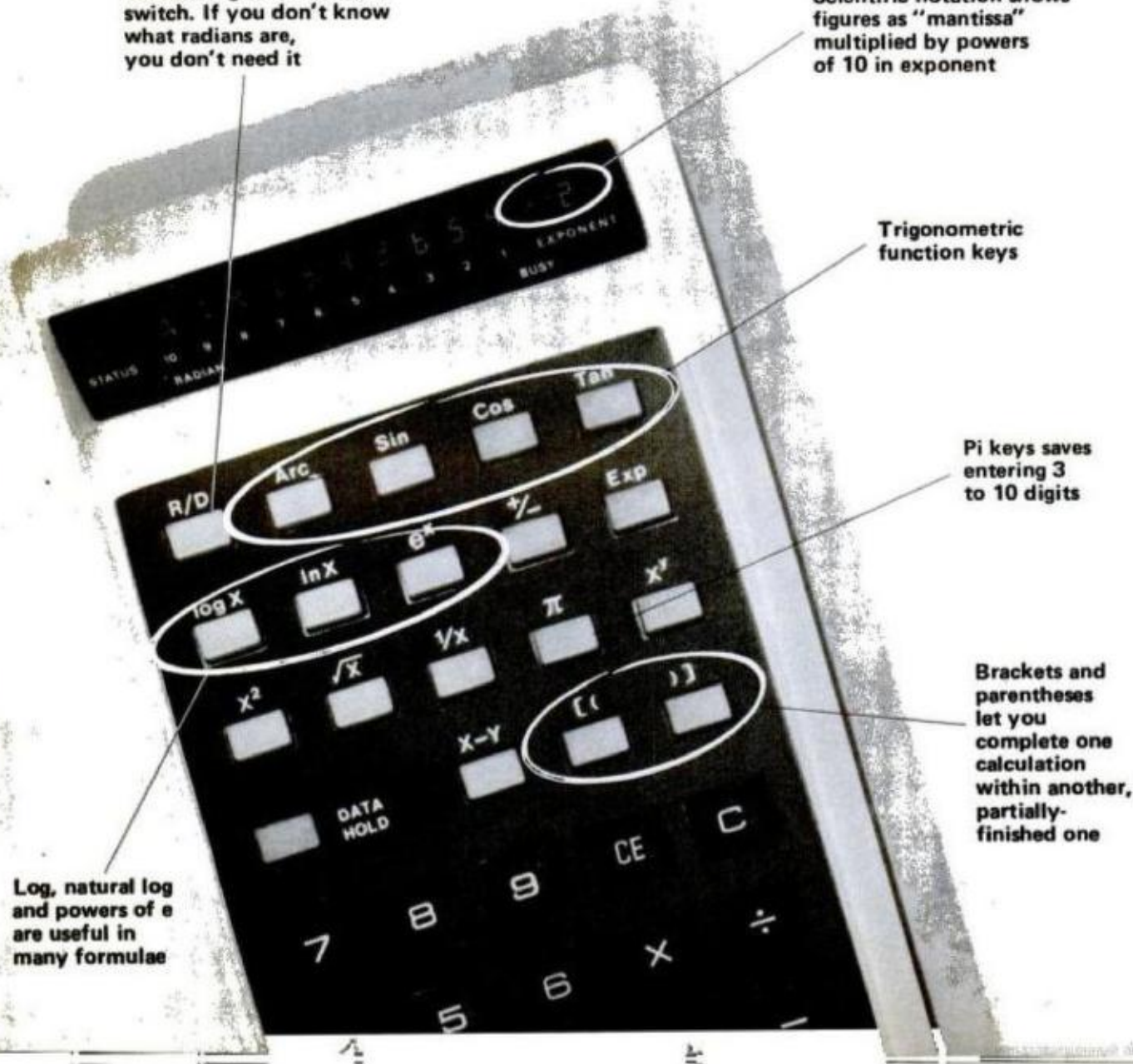
Scientific notation shows figures as "mantissa" multiplied by powers of 10 in exponent

Trigonometric function keys

Pi keys saves entering 3 to 10 digits

Brackets and parentheses let you complete one calculation within another, partially-finished one

Log, natural log and powers of e are useful in many formulae



than one for your family or business, make sure they all use the same entry system.

A "clear" key is a must, and a separate "clear entry" key is a major convenience if you ever do long calculations. The clear key erases the whole calculation and resets the machine to zero—handy, if you find you've set the calculation up wrong, or made an error a few steps back. Clear entry keys just erase the last entry you made, so you can correct that without disturbing all the correct steps you've made before. Some calculators have a single CE/C key, whose first stroke clears the last entry, and whose second clears the entire example; this is probably almost (but not quite) as convenient.

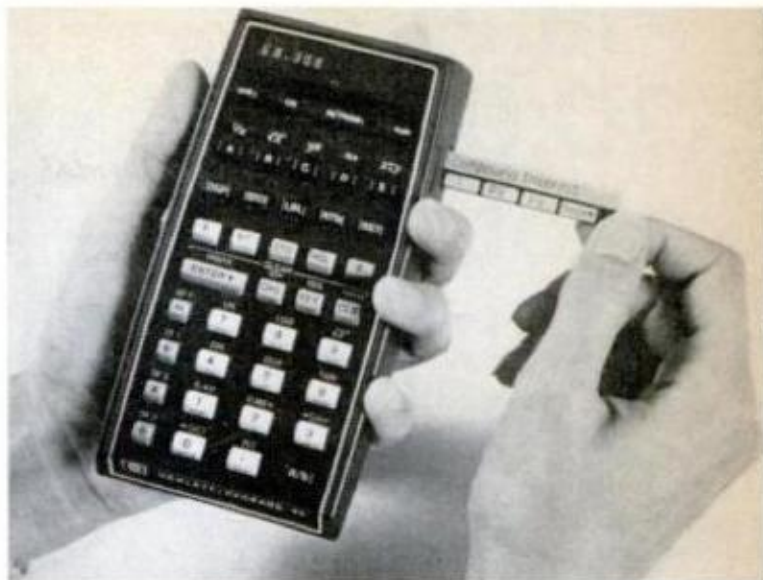
For common *percentage* calculations, such as discount, tips and taxes, many calculators have percentage keys which automatically adjust the decimal point as needed.

Memory and *constant memory* are useful extras found on many middle-priced machines. The constant memory lets you repeatedly multiply or divide by the same number without having to re-enter it each time (and often lets you add or subtract it repeatedly as well). A K switch or button is a common sign of a constant memory, though many calculators without the switch still have a constant memory built in (for instance, the Sinclair, the Panasonic and the Casio did). On such machines, once you've multiplied a number by the desired constant, all you have to do to multiply another number by the constant is to key in that number and the equals sign.

You can also square a number on a constant-memory machine by keying in the number, X and =.

The accumulative memory, shown on the Casio on page 72, is a bit less common. It automatically adds together all totals of a series of intermediate calculations: Every time you hit the "equals" key, that result is added to whatever is in the memory. A typical application would be making invoices: Multiply a dozen apples at 12 cents apiece (\$1.44) and 16 clams at \$1.25 per dozen (\$1.666...) and all you have to do is press the recall button (T on the Casio) to get the total of the invoice; \$3.1066... or \$3.11.

On some machines, the Casio included, if you shut off the accumulator, you can still recall and use its contents though further totals won't be added to the memory. To



Calculator you can program to perform sequences of operations automatically is Hewlett-Packard's \$795 HP-65; 950 premade programs are also available.



Business calculators are as complex as scientific types, but are preprogrammed for typical business calculations. Hewlett-Packard's new HP-70 costs \$275.

subtract a total from the accumulator, there's usually a red = key.

A *single-key memory* has a single M key that performs two functions: Press it while there's a number on the display, and the memory will clear itself, then memorize that number; press it after a function key (+ or X, for instance), and it will recall the memorized number to the display.

Full-control memories have keys labeled M+, M-, MR and sometimes MC. Pressing the first of those keys adds the number on the display to the memory; pressing the second subtracts the displayed number from the memorized total; pressing MR brings the total from the memory to the display;

(Please turn to page 168)

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Popular Mechanics

**OUR NEXT EARTHQUAKE:
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OF FRONT-
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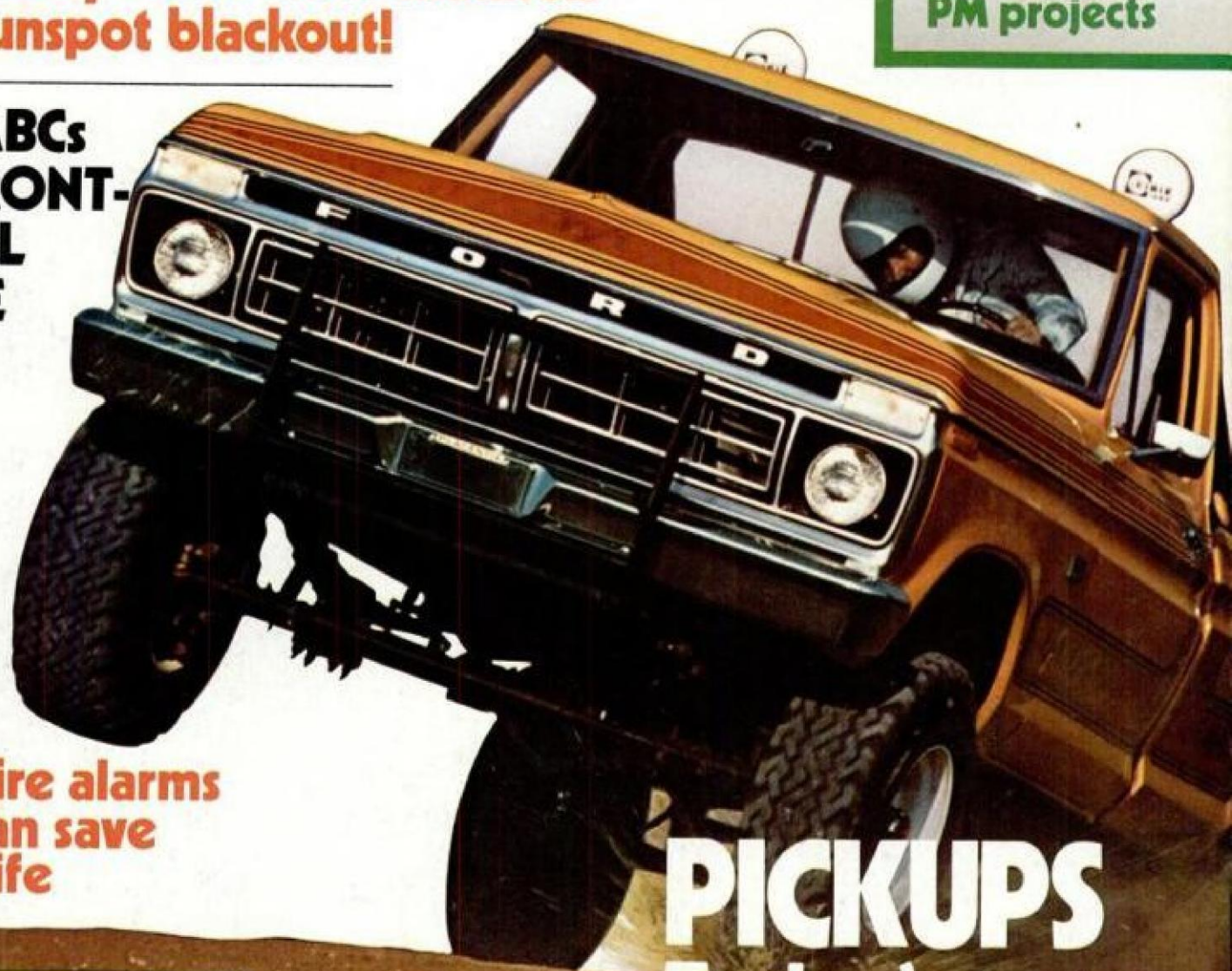
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TODAY'S FORECAST:

EARTHQUAKE!

On the western edge of the Mojave Desert, north of Los Angeles, the land is rising like bread dough on a warm radiator. Since 1960 a huge kidney-shaped area of 10,000 square miles has uplifted more than a foot in many places. Scientists of the U.S. Geological Survey are watching the region like hawks.

Radio stations in Southern California have even put Bugs Bunny to work warning people what to do when a quake hits. The uplift straddles a sector of the San Andreas Fault that has remained "locked" since the great quake of 1857. Hence, say the experts, strain may be building up in the area.

According to Dr. Robert Hamilton,

Can man
beat nature's most
devastating event?
Scientists say
quake predictions are
a realistic goal.

by Richard F. Dempewolff
and
Mike McClintock
HOME AND SHOP EDITOR

When built-up stresses in the San Andreas Fault (arrow) are released, huge manmade structures are shaken to destruction.



chief of the USGS Office of Earthquake Studies, ground swelling preceded a 1971 San Fernando temblor (earthquake tremor) as well as one that shook Niigata, Japan, in 1964.

Geophysicist Dr. Barry Raleigh, at USGS field headquarters in Menlo Park, Calif., adds the historic case of a village on the Japan Sea, where people woke one morning to find that their bay apparently had "gone to sea" overnight. Suspecting the ocean had receded due to an imminent tidal wave from a distant storm or volcanic eruption, everyone made for the hills. Nine hours later a devastating earthquake destroyed their town. The bottom of the bay, which actually had uplifted several meters in 12 hours, subsided again, and the sea rushed back, sweeping everything before it including the villagers who had returned to see what the quake had done to their homes. The notable fact, duly documented, is that a massive uplift preceded the quake.

However, existing records don't prove that *every* earthquake is preceded by uplift. But this phenomenon, along with other activity now known to precede some quakes, soon may tell geophysicists where, when, and how destructively the next big shake-up will occur.

Prediction progress

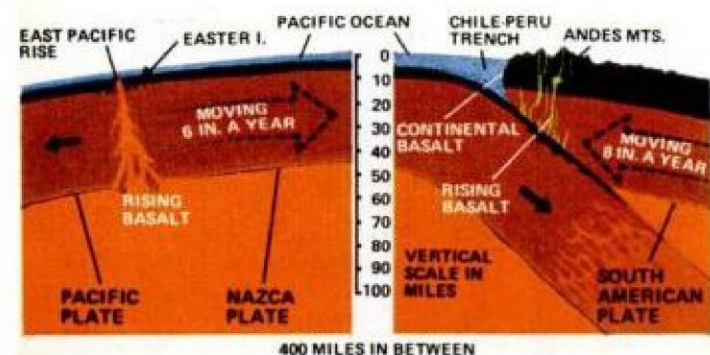
Already, scientists in the United States and elsewhere have predicted with fair accuracy a number of local temblors. In November 1974, geophysicists at Menlo Park had the data to predict a magnitude-5 earthquake near the month's end epicentered at the town of Hollister. On the 28th, a slightly lesser quake struck just south of Hollister. Since the forecast was a test, no public warning was issued.

At Blue Mountain Lake in New York's Adirondacks, in 1973, evidence of a potential quake turned up in velocity patterns of seismic waves propagating through the crust. Other instruments confirmed that something was happening in the bedrock. Dr. Yash Aggarwal, a Lamont-Doherty Geological Observatory scientist, calculated that an earthquake of 2.5 magnitude or greater would hit within four days. A couple of nights later, at dinner, Aggarwal thought he felt a shudder, checked his seismographs and discovered that a 2.6 quake had quivered through the scenic mountain area he'd specified.

And recently, the National Research Council's Panel on Earthquake Prediction ventured an opinion that "a scientific prediction will probably be made within the next five years for an earthquake of magnitude 5 or greater in California."

Life-saving predictions

In China, where 10,000 quake-teams monitor that geologically restless country's quake precursors, more than 10 successful predictions have been made and warnings



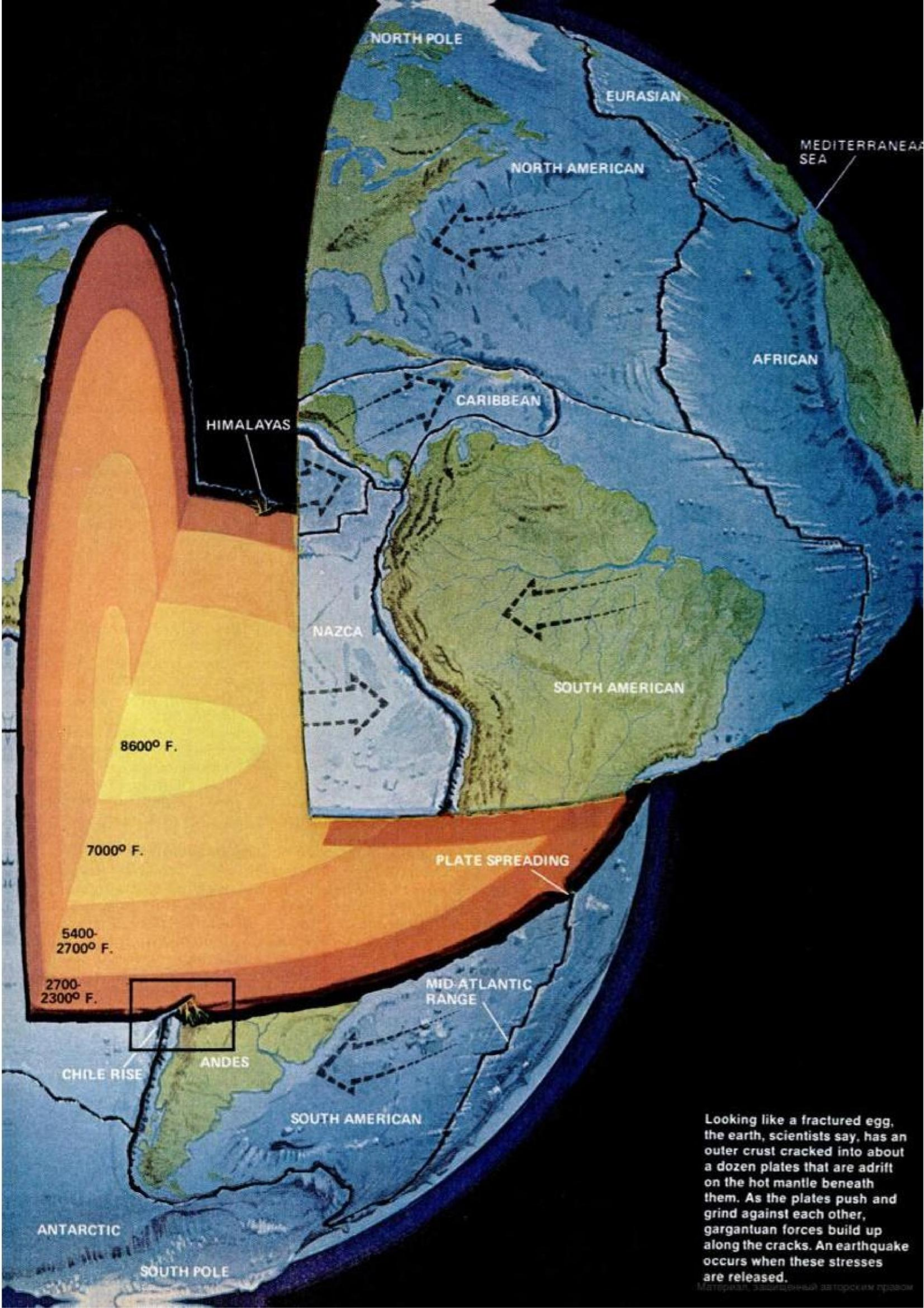
Something's got to give when two plates meet. The inset shows the Nazca plate being bulldozed into the earth's molten core.

Great plates of the earth



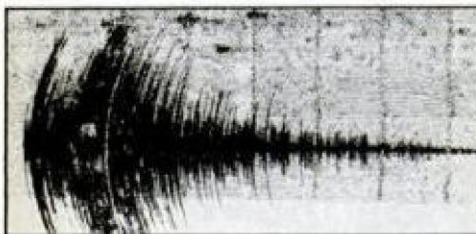
NOT VISIBLE: CHINA AND INDIA-AUSTRALIA PLATES

PM art: Ed Valigursky



Looking like a fractured egg, the earth, scientists say, has an outer crust cracked into about a dozen plates that are adrift on the hot mantle beneath them. As the plates push and grind against each other, gargantuan forces build up along the cracks. An earthquake occurs when these stresses are released.

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Laser ranging devices (right) are part of the new arsenal of earthquake-prediction equipment. They can detect minute changes in land formations. Scientists can "read" quakes on seismometer printouts.



issued. The accurate forecast of a big one recently saved thousands of lives. It began in 1970, when instruments provided a number of clues that crustal changes were occurring around Haicheng on the Liaotung Peninsula in southern Manchuria.

During the next four years, reports of anomalies increased and a 4.8 foreshock hit the region. By February 1975, the scientists were sure; a crash warning was issued predicting a major quake within two days. An hour later, tens of thousands of people were moving from their homes, carrying the old and sick to places of safety outdoors. In some villages, officials showed outdoor movies to coax out those reluctant to leave. Less than six hours after the alert, a 7.3-magnitude earth-shaker brought down virtually every building in Haicheng, but casualties were light.

With such success, what happened at Tientsin, Tangshan and Peking last July? Reuters news service estimated that up to 800,000 people perished in that immense 8.2 quake—which would make it the second worst in recorded history. (An 8.5 shake-up in Shensi, China, took 830,000 lives in 1566). Actually, China's earthquake team *had* forecast last July's quake. Ominous magnetic changes had been noted, along with other precursors. Last year, radio stations began to warn the teeming populace of affected cities to prepare for a great earthquake. Whether or not a last-minute alert went out is not known.

Earth like a cracked egg

Only for the past decade have geophysicists known enough about the staggering forces that cause earthquakes to do much about them. The opportunity for predicting them

began with the astonishing discovery that the earth's surface is not one continuous sheath like the glaze on a candied apple. Our continents and ocean basins are adrift on the hot plastic mantle underlying them. According to this new view, called "plate tectonics," the earth's 30-to-60-mile-thick global crust is fractured, like the cracked shell of an egg. As researchers probe deeper into the ocean-bottom trenches and continental land masses that cut into the crust, they begin to see a world in which those vast sections of thick crust are in constant, thrusting, dynamic motion.

Evidence in the deep-drill cores brought up by scientific teams indicates that for more than 4 million years, those gigantic plates have been jostling and grinding their rock-faced edges against each other—separating to create oceans, squeezing shut with crumbling pressure, overriding each other like ice floes on a polar sea—driven slowly but inexorably by gargantuan forces deep in the earth's molten interior.

Unraveling nature's secrets

This exciting concept provides elegant answers for many geological mysteries that have plagued scientists for centuries. It explains the jumbled formation of our jagged coastal sierras; what sea-bottom fossils are doing in rocks on Everest's peak; why volcanic archipelagos stream across the ocean floors in continuous chains; how the fossilized remains of an African reptile turned up in sedimentary rock layers of Antarctica. It also explains the strange, cloven structure of submarine mountain ranges and provides the long-sought primeval mechanics of volcanoes and earthquakes. The plate concept holds that:

■ The earth's crust is made up of about a dozen major plates, with many fractures and subdivisions.

■ The present land masses, embedded in crustal basement rock, once formed a single continent that began splitting up about 200 million years ago. For years, school kids have noticed that many continental shorelines "match" but scientists have been hard-put to explain this "coincidence." The plate theory does it neatly. It proposes that molten material from the earth's hot mantle forced its way through rifts in the sea floors, hardening against each side and forcing them apart at a rate of one-half to three inches a year. Plates thus formed moved off, carrying continental land masses with them like flotsam frozen in vast ice sheets, eventually rafting them to their present locations.

Something has to give

■ As volume is added to the crust by molten rock welling up through those mid-ocean ridges, something has to give—and does. Plates are squeezed by immense forces, with spectacular results. Over the eons, edges crumble into gigantic blocks. They fold and rumple like rug edges shoved together. The lighter sedimentary and granitic rock of the continental plate may grind over the top of the ocean-bottom plate of heavier basalt, bulldozing sediments and rock debris, piling it in a massive jumble of coastal mountain ranges.

The overridden plate presses downward, forming deep trenches like the Marianas and Puerto Rico deeps, as it is thrust down into the hot mantle where it returns to a molten state, completing the cycle. In the grinding process, pockets of white-hot lava may be trapped, eventually

pluming through fissures to the surface and erupting in volcanoes.

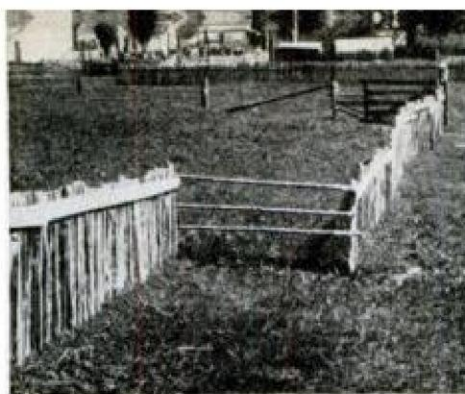
■ As a plate inches along over such a volcanic fissure, the plume of magma punches hole after hole through the crust in a sort of belt-line production of volcanic islands such as those in the Hawaiian chain.

■ Deep earthquakes that shake the entire planet, pinpointed by seismographs at depths down to 400 miles in the ocean trench regions, are thought to be the rumblings of that thrusting, elephantine digestive system of overriding plates. Catastrophic surface quakes, like those along California's San Andreas Fault and the Altyn Tayh Fault in China, are the result of plate edges shearing and grinding as they slip after years of remaining "locked."

Signs quake-watchers look for

Now, with a whole new body of knowledge pouring in from the field, geophysicists are finding ways to measure and evaluate the events that precede earthquakes. In more than 25 cases, Menlo Park instruments have picked up precursory anomalies of quakes that occurred. In 10 other cases, however, the quake didn't ensue. Dr. Raleigh indicates that's not good enough. For prediction to work, he points out, forecasts must meet all criteria, including:

- Accurate location of the epicenter.
- Calling intensity within a few



Fenced-in property lines get lost in the shuffle when an earthquake rumbles by. Where fault lines run through populated areas, sudden quakes can be catastrophic.

tenths on the 1-to-10 Richter scale.

- Naming the day and approximate time the quake will hit.

- Providing a long-range prediction to allow for preparation, as well as a flash warning within a few days of the expected event.

To achieve such accuracy, a battery of techniques—some new, some old—is being brought to bear.

In repeated observations, it has become apparent that swelling of land prior to many quakes involves the appearance of myriad "micro-cracks" in the rock—a phenomenon called "dilatancy" caused by stresses.

New tipoffs to coming quakes

The Russians discovered that speed of seismic waves in bedrock often slows long before a quake, increasing

again just before it occurs. Today, along the San Andreas Fault, dozens of seismometers monitor seismic velocities in the ground by measuring waves from quarry blasts. "According to the Russians," says Raleigh, "the time scale in which the decrease and rise occur is proportional to the quake that hits."

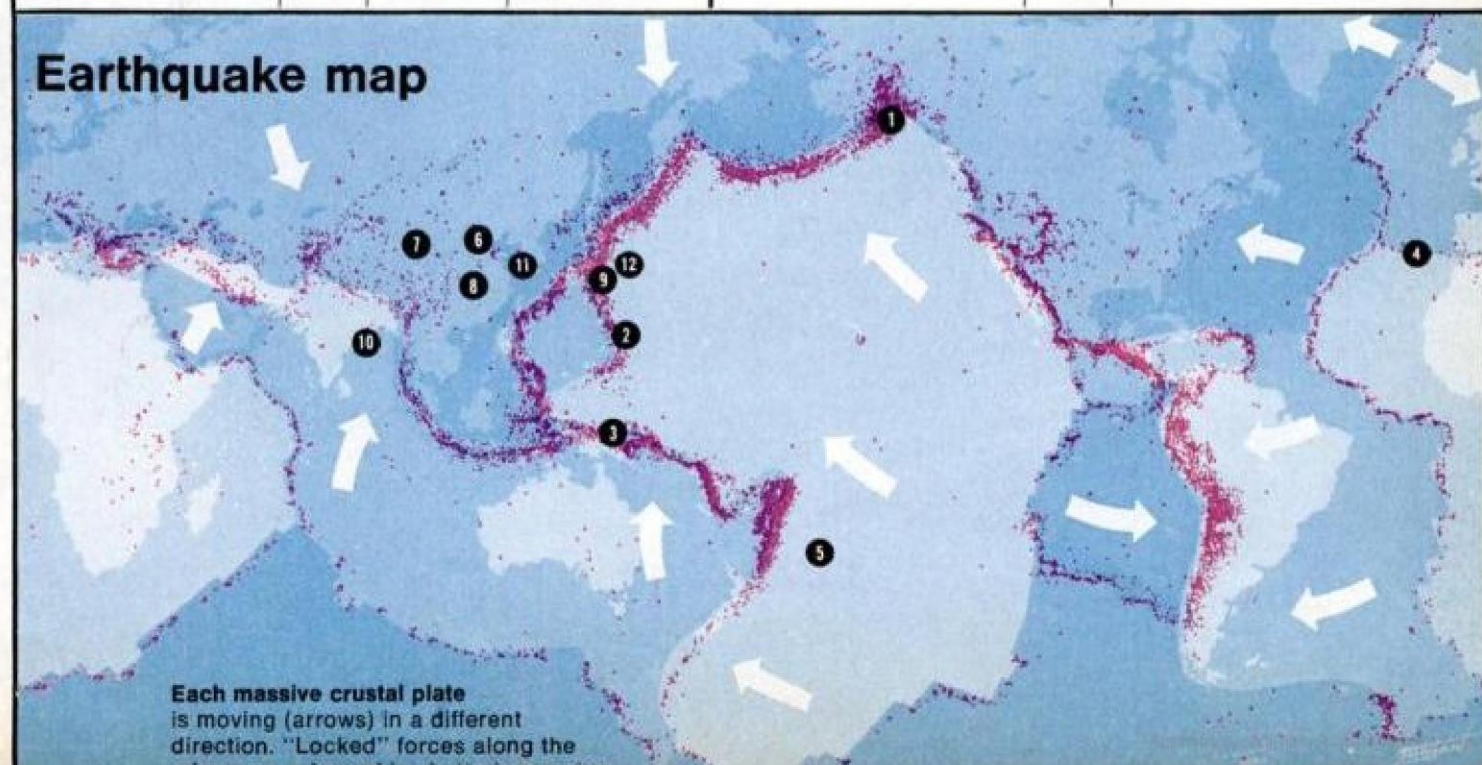
At Stanford University, geophysicist Dr. Amos Nur discovered that during dilatancy, ground water fills the microcracks, probably causing the decrease in seismic velocity, as well as other curious phenomena, including changes in the level of well water. "Groundwater," explains the Office of Earthquake Studies' Dr. Joseph Ziony, "seeps into cracks of rock under stress and you get a drop in well levels. As voids are filled, the level comes back." In the stresses just preceding a quake, cracks close, sending water up dramatically.

The Chinese, for instance, observed that just prior to a quake ordinary wells sometimes went "artesian," flowing out over the surface.

In China, where Dr. Raleigh and other geophysicists saw thousands of volunteers and scientists at work in 1974, and again last summer, interesting approaches are afoot. "Amateurs monitor wells, plus pairs of electrodes that they poke in the ground 100 feet apart to measure

(Please turn to page 131)

BIGGEST QUAKES IN RECENT YEARS				QUAKES CAUSING THE MOST CASUALTIES		
Place	Year	Richter No.	Casualties	Place	Year	Casualties
1. Anchorage, Alaska	1964	8.5	131	1. Chihli, China	1290	100,000
2. Philippine Sea	1968	8.0	None	2. Shensi, China	1556	830,000
3. New Guinea	1971	8.0	None	3. Tokyo, Japan	1703	200,000
4. North Atlantic	1975	8.0	None	4. Calcutta, India	1737	300,000
5. Off Kermadec I., N.Z.	1976	8.0	None	5. Kansu, China	1920	180,000
6. Near Tientsin, China	1976	8.2	600,000-800,000 (Reuters est.)	6. Yokohama, Japan	1923	143,000
				7. Near Tientsin, China	1976	600,000-800,000 (Reuters est.)



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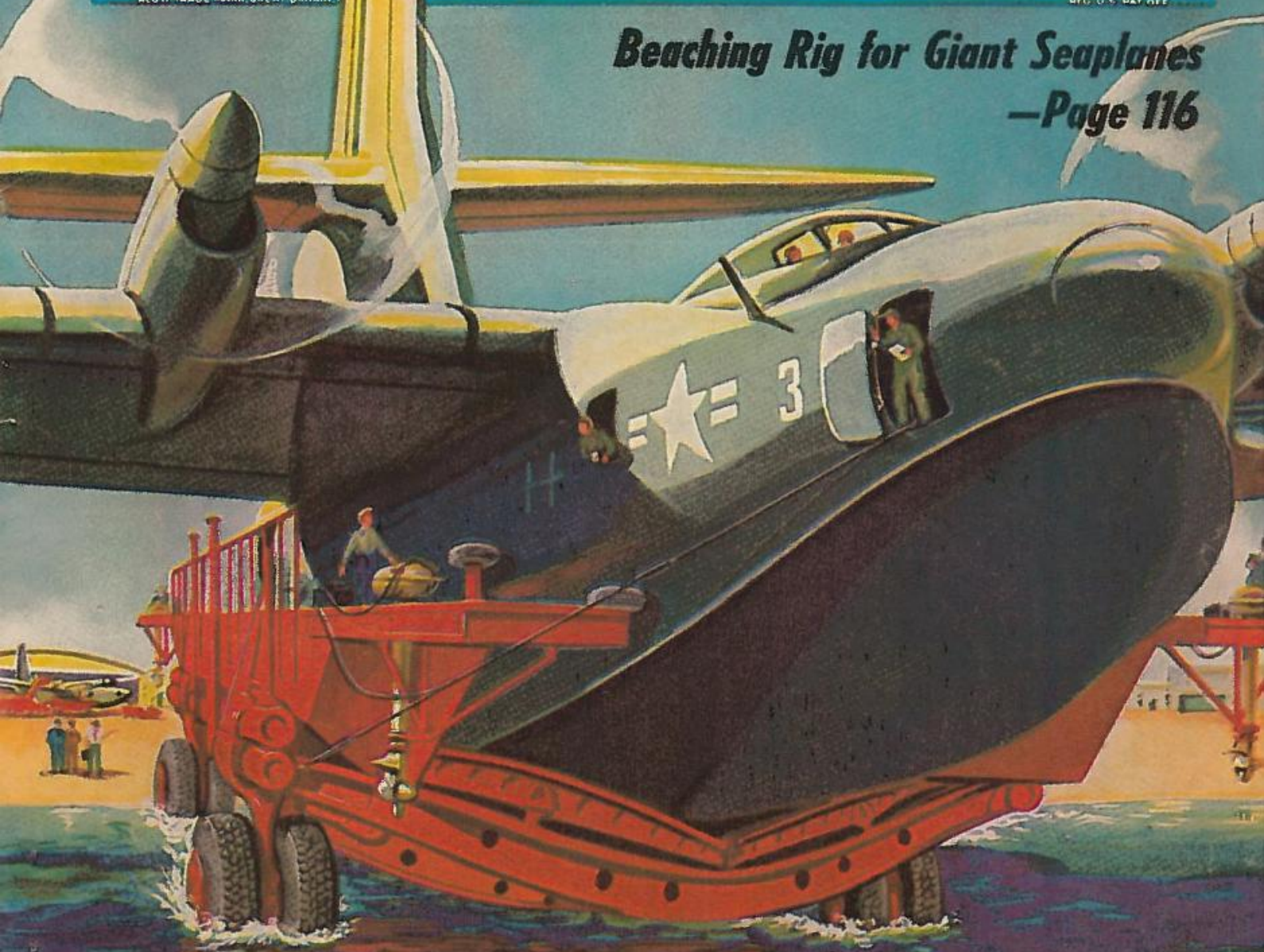
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Beaching Rig for Giant Seaplanes
—Page 116



**What Owners Say About the
'55 PONTIAC**

HAVE WE SENT A ROCKET INTO SPACE?

For the Craftsman
BUILD YOUR OWN AIR BOAT



POPULAR MECHANICS

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VOL. 103 NO. 5

With his Gargantuan machines
Robert G. LeTourneau can pick up a house or mow down a forest

He's Changing the Face of the Earth

By Paul Lee

THE RED DUST near Longview, Tex., billows out in pink clouds as a monster lumbers up to a wood lot, digs in and in one shuddering effort pushes over a huge tree, root system and all. Nearby, another machine rolls through the grove, knocking over trees and smashing them to pulpwood.

These are just two samples of a new breed of mechanical monsters—land-clearing machines—designed to clean up the face of the earth. They bear the name LeTourneau—a name that has been synonymous

Tree roller, shown here and at top of page, climbs trees until they topple, then grinds them to pulp





Tournatrail has short turning radius but is longer than a football field. Left, huge cab has seats for crew of seven. Bottom, ingenious linkage makes all cars follow same path during a 90-degree turn

with earthmoving for decades. More than half the earthmoving equipment in the world was designed by Robert G. LeTourneau and built in his factories.

Suddenly, about a year ago, LeTourneau sold his entire earthmoving business for \$31,000,000 and, at the nominal retirement age of 65, embarked on a brand-new crusade—land clearing.

Why?

To discover the answer you must turn to the man himself. LeTourneau is much like the machines he builds: big, awkward, but unbelievably efficient. When he pushes, something gives, and he can race through an impressive amount of work between 7 a.m. when he bursts into action and 10 p.m. when he seems to switch off his energy for a few hours.

LeTourneau never finished high school, yet he is an outstanding engineer and inventor. For proof, take a look at his machines, which now churn through mud and swamp the world over.

To LeTourneau, the curtain is going up on a big-business drama. The millions in the cast include a baby crying for food, a farmer in Peru and your own grandchild.



Tournalayer totes a steel form containing a concrete house from the casting site to a prepared foundation

The stage setting for this drama can best be expressed in figures. By the time you reach the end of this article there will be 85 more mouths to feed in this country. Tomorrow our population will have increased by 6000, and a year from today 2,000,000 more people will be sitting down to the dinner table.

Despite this population boom, we have fewer acres of farm land than we had 30 years ago. For every acre we add for food production, we lose more than an acre to expanding cities and superhighways. Sometime before 1975, according to a recent survey, our ascending population curve will intersect the line showing our

production of food and fiber. At that moment we'll step from surpluses to shortages.

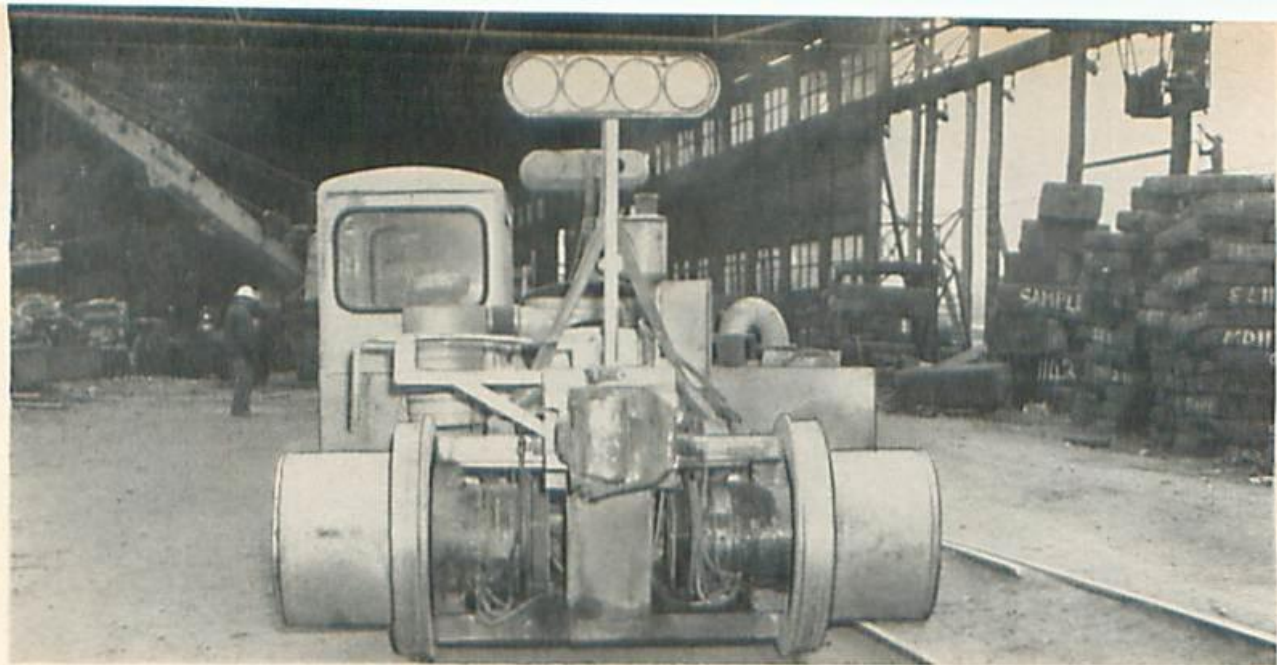
How will our children, our grandchildren fill their dinner plates?

Several answers have been proposed: Increased use of machines and fertilizers, new sources of food from the ocean, higher yields through hybrids.

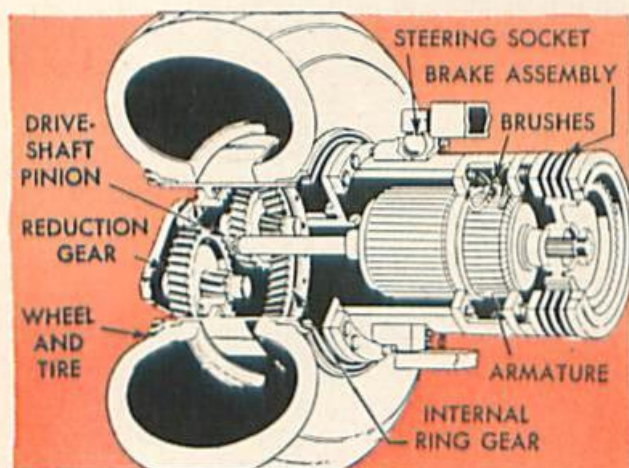
But the short-term answer is simply to increase the number of acres under cultivation. In this country there are 50 or 60 million acres of fertile land covered by unproductive trees and brush. And more important, an umbrella of rain forest covers billions of acres of potentially good farm land in Africa and South America.

U-shaped Tournalayer also can pick up an existing building weighing 150 tons and move it to new location





Even the switch engine used in the LeTourneau steel mill is equipped with an electric motor on each wheel



Motor in each hub gives machines flexible power. If three wheels are stuck, fourth draws all the power

Against this backdrop, the drama is simply the age-old story of man against nature. But the tools man will be using are something new on the face of the earth which they are destined to change. Surprisingly few machines have ever been designed specifically for land clearance. Most of our present farm land was cleared by ax blade and blister. Recently a few earthmoving machines such as bulldozers have been adapted for land clearance.

Now a new technology is unfolding. Several firms are designing 20th-century versions of the colonial farmer's ax. The strangest, biggest and perhaps the most efficient machines have been born on the

(Continued to page 238)

Sno-Buggy, posed in front of LeTourneau-designed building, has eight 10-foot tires that "float" it on snow



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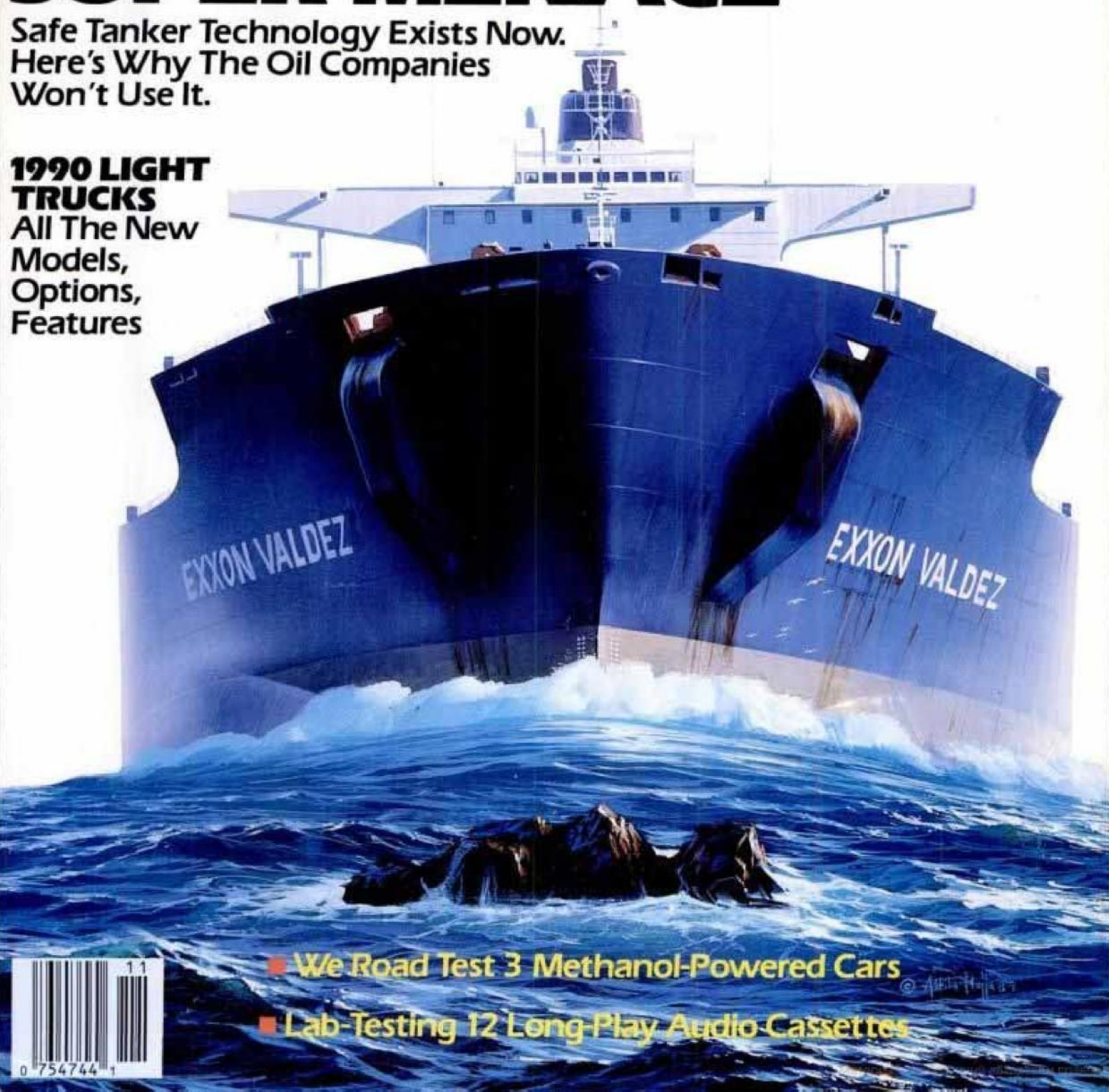
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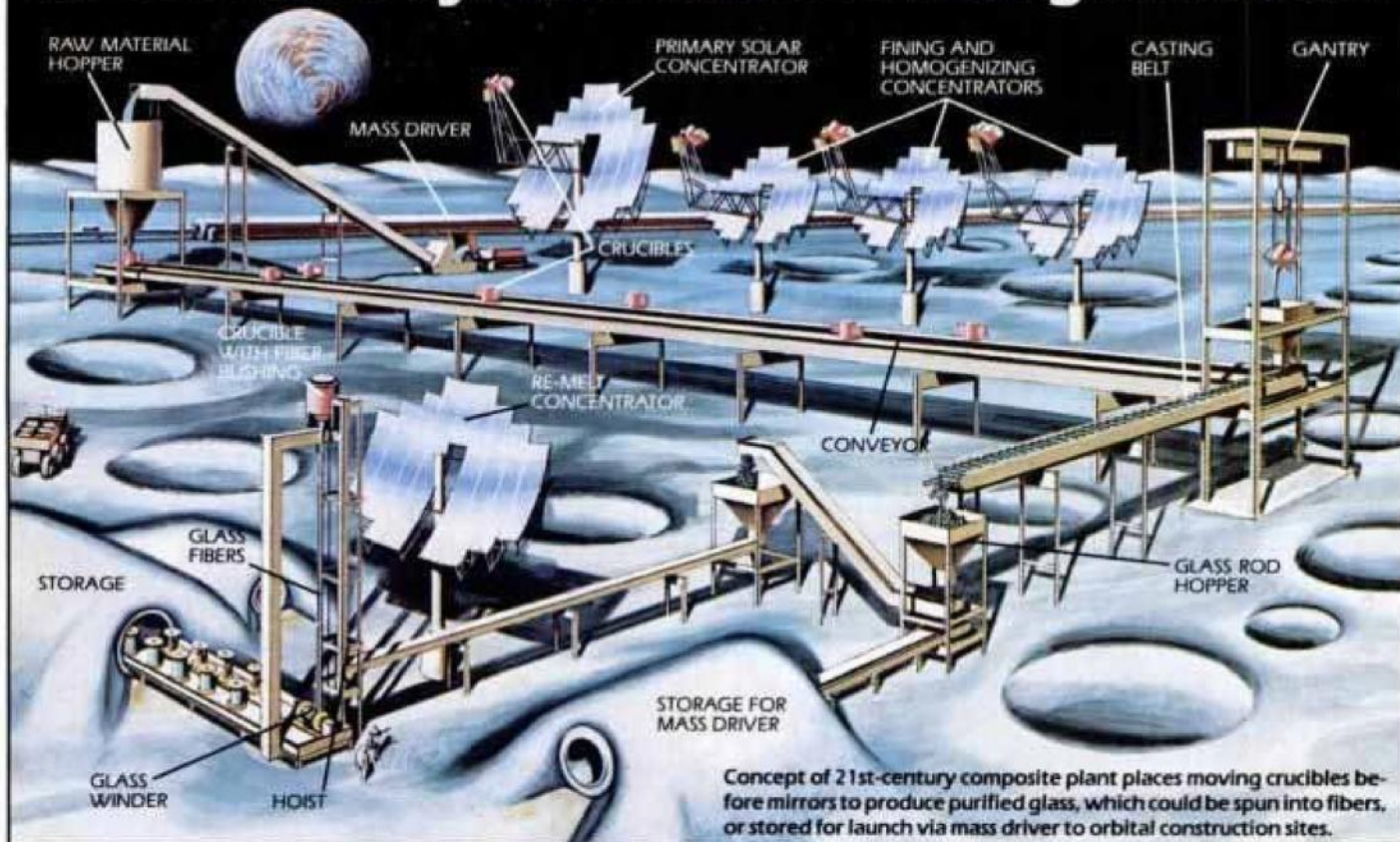
■ Lab-Testing 12 Long-Play Audio Cassettes



TECH UPDATE

News Of Tomorrow's Technology Today

Moon Factory Will Make Building Materials



Concept of 21st-century composite plant places moving crucibles before mirrors to produce purified glass, which could be spun into fibers, or stored for launch via mass driver to orbital construction sites.

PM ILLUSTRATION BY ADOLPH E. BROTHMAN

TORRANCE, CA—By spinning composite fibers from moon dust, a solar-powered installation now being studied by Goldsworthy Engineering, Alcoa, McDonnell Douglas and Princeton's Space Studies Institute could open the way to lunar colonization without importation of materials from Earth. The tremendous cost of such imports is the main obstacle to producing structures on the Moon.

Samples of lunar regolith brought back by the *Apollo* missions show the presence of large concentrations of feldspar and basaltic rock—substances that would produce fibers comparable in strength to terrestrial glass.

To make fibers, rock is first melted in crucibles held at the foci of parabolic solar

reflectors, then allowed to fall in thin strands through a platinum bushing, and wound onto spools.

The greatest challenge is producing substitutes for the organic resins with which fibers are normally impregnated. Current plans call for using a small reflector to fuse flakes of the fiber material into mats of fiber to produce solid panels.

The first plant landed on the Moon would probably be a lightweight version, with a single reflector adequate to produce fiber for simple shelters. Later, additional mirrors could be landed to maintain the temperatures for homogenizing and fining, or

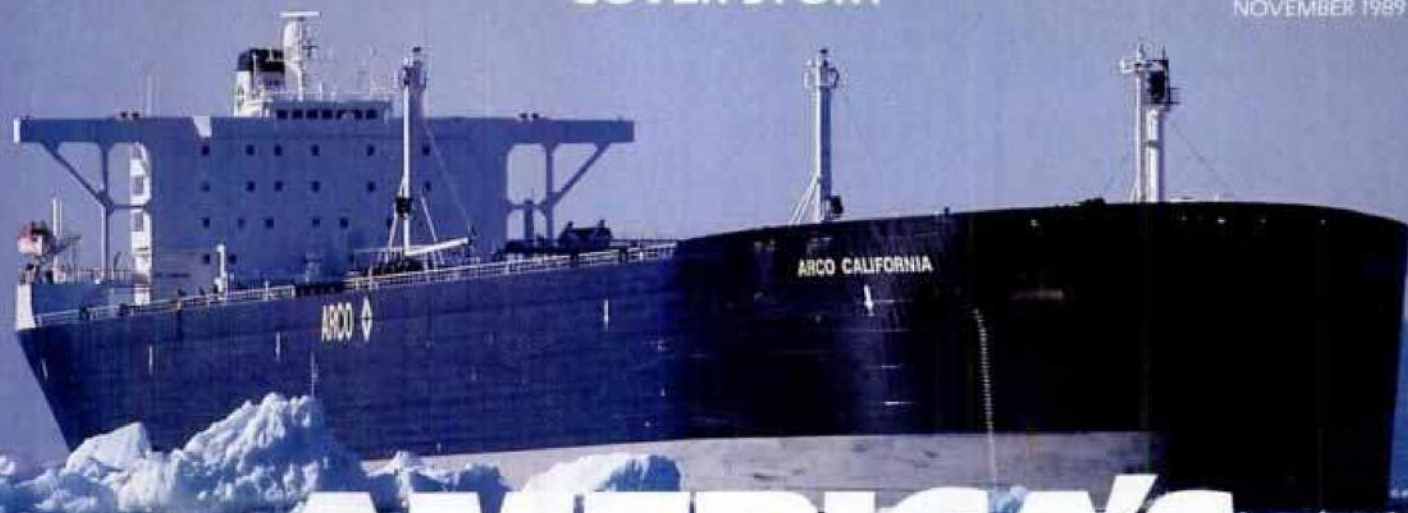
purification, of the glass. The resulting high-quality fiber could be launched from the

Moon with magnetic mass drivers to build space stations and satellites.

Highlights This Month

- **Stargazing**—Computer-aided optics pierce Earth's atmospheric boundary.
- **Hypervelocity Impact**—Helium gun aids study of micrometeor hazards.
- **Biotechnology**—Living, manmade matrix replaces blood vessels.
- **Parallel Progress**—Innovative architecture speeds supercomputing.
- **Air Power**—Massive research effort spurs jet-engine advances.
- **Ocean Architecture**—35-story concrete barrier floated to North Sea platform.
- **Energy For Tomorrow**—Self-cooling reactors may revive nuclear power.

Editor: Tim Cole
Assistant Editor: Abe Dane
Contributors: Mike Fillon,
Thomas G. Murphy



AMERICA'S OIL TANKER MESS

Industry's failure to implement improvements in oil tanker design is a leading cause of current environmental disasters.

FOUR MINUTES after midnight on March 24, miles off course and with an unlicensed and increasingly panicked third mate in command of the bridge, the full 246,000-ton weight of the supertanker *Exxon Valdez* focused itself on a pinnacle of rock. Penetrating $\frac{3}{4}$ -in., high-tensile steel to a depth of 3 to 5 ft., the point carved along the ship's underside from the forepeak to just

BY ABE DANE

ahead of the engine room, and brought the ship from a speed of 12 knots to a dead stop. A second, more crushing impact came moments later, when the ship pivoted and came to rest on a ledge. Eight of the 11 cargo tanks were ruptured, and oil surged out with such force that it burst to the surface in 3-ft.-high waves.

The first fully equipped cleanup team didn't arrive for 14 hours, 9 hours longer than was called for in contingency plans. In the chaotic days that followed, it became clear that Exxon, the Coast Guard and the Alyeska Pipeline Service Co. had nothing like the resources needed to combat the spill. It soon spread to the size of Rhode Island, and an Exxon official conceded, "We will never get



The wreck of the *Argo Merchant* off Nantucket (left) foreshadowed the grounding of *Exxon Valdez*, shown offloading cargo into smaller

vessel (right). Nosing through ice in Prince William Sound, the double-bottomed *Arco California* (top) represents a possible solution.

AMERICA'S OIL TANKER MESS

back most of those 240,000 barrels."

Thus, Prince William Sound became an environmental Pearl Harbor. The damage was staggering, with cleanup costs likely to exceed \$1 billion, a \$150-million-a-year fishing industry threatened, and an enduring stain left on a part of the world that residents justly think of as God's country. Secretary of Transportation Samuel K. Skinner declared the spill to be "one of the worst environmental and economic disasters this nation has ever faced."

As if to drive the message home, three smaller but still serious spills occurred exactly three months after the *Valdez* accident. In one extraordinary weekend, spills of between 250,000 and 420,000 gallons each fouled the waters of Rhode Island, Delaware and Texas.

So far, investigations have laid responsibility for all of the accidents to mistakes by crewmen. But they have also raised disturbing questions about equipment and procedures.

Six parts oil, one part steel

Modern tankers are uniquely fragile and unwieldy vessels. According to Lincoln Crane, chief of the Stability and Control Division of the Davidson Laboratory at the Stevens Institute of Technology, the idea in tanker design is "to get as much cargo as you can into as little steel as possible, and still have economical propulsion." The larger the ship, the simpler this task is to accomplish. As a result, over the past three decades the largest tankers have grown from vessels of no more than 121,000 tons into quarter-mile-long behemoths displacing 640,000 tons, and drawing up to 90 ft.

ULCCs, or Ultra Large Crude Car-

riers as these ships are called, require 3 miles and 20 minutes to stop from a top speed of 15 to 16 knots. To make matters worse, the low ratio of steel to cargo—1:6 in the case of the *Exxon Valdez*—makes them vulnerable to rupture at the gentlest brush with an unyielding object.

The double-hull controversy

Of the safety measures now being considered, none has inspired more heated debate than a proposed requirement that a second layer of steel



First of three in a weekend, the *World Prodigy* spill coated the shores of Rhode Island.

be laid inside a ship's framework, resulting in either a double bottom or double hull (see illustrations opposite). Hardly an untried idea, twin skins of one kind or another are present on virtually all of the 60,000 merchant ships afloat—except for oil tankers.

Double hulls are already required on tankers carrying hazardous cargoes such as liquefied natural gas, and more than once have been credited with preventing disaster.

On July 1, 1979, the LNG tanker *El Paso Paul Keyser* steamed onto a rock ledge in the Strait of Gibraltar at a speed of 17 to 18 knots. Although the outer hull was torn open under four of



the six cargo tanks, the inner hull suffered only a minor dent, and none of the 95,000 cubic meters of highly volatile cargo escaped.

Experiences such as this are backed up by several studies. A 1975 Coast Guard analysis of 30 oil-tanker groundings concluded that double bottoms with a 2-meter separation between the layers would have prevented spills 96 percent of the time. Studies by Congress's Office of Technology Assessment, the National Transportation Safety Board and others provided supporting evidence.

In the wake of the 1976 wreck of the *Argo Merchant*, which introduced 7.6 million gallons of oil into the waters off Nantucket, President Carter proposed that double bottoms be required on all tankers over 20,000-tons dead weight (the weight of the ship's cargo alone). The measure was rejected, however, by a convention of maritime nations, and replaced by one calling for segregated ballast tanks (see illustration above). Set aside strictly for seawater ballast, carried to stabilize the ship when it is empty of oil, these tanks are placed so as to provide some protection against collision.

Justifying the move, the oil and shipping industries offered two basic objections to twin skins. First, they said, oil could leak into the void space between the inner and outer plating, forming a vapor that could explode. But, according to Arthur MacKenzie, who was on the OTA panel that studied tanker safety in the 1970s and now runs a casualty reporting service called the Tanker Advisory Center, there has not been one explosion attributed to a double hull or double bottom in the past 25 years, although some 530 tankers have them.

The industry also claimed that if the outer layer of a twin-skinned tanker were breached, water filling the void space could cause the ship to lose buoyancy and come harder aground, increasing the difficulty of salvage and possibly causing it to capsize.

OIL TANKER PROFILES



EASTERN SUN—Length: 641 ft. Capacity: 30,252 tons.



TEXAS SUN—Length: 752 ft. Capacity: 50,864 tons.



MEDITERRANEAN SUN—Length: 889 ft. Capacity: 134,835 tons.



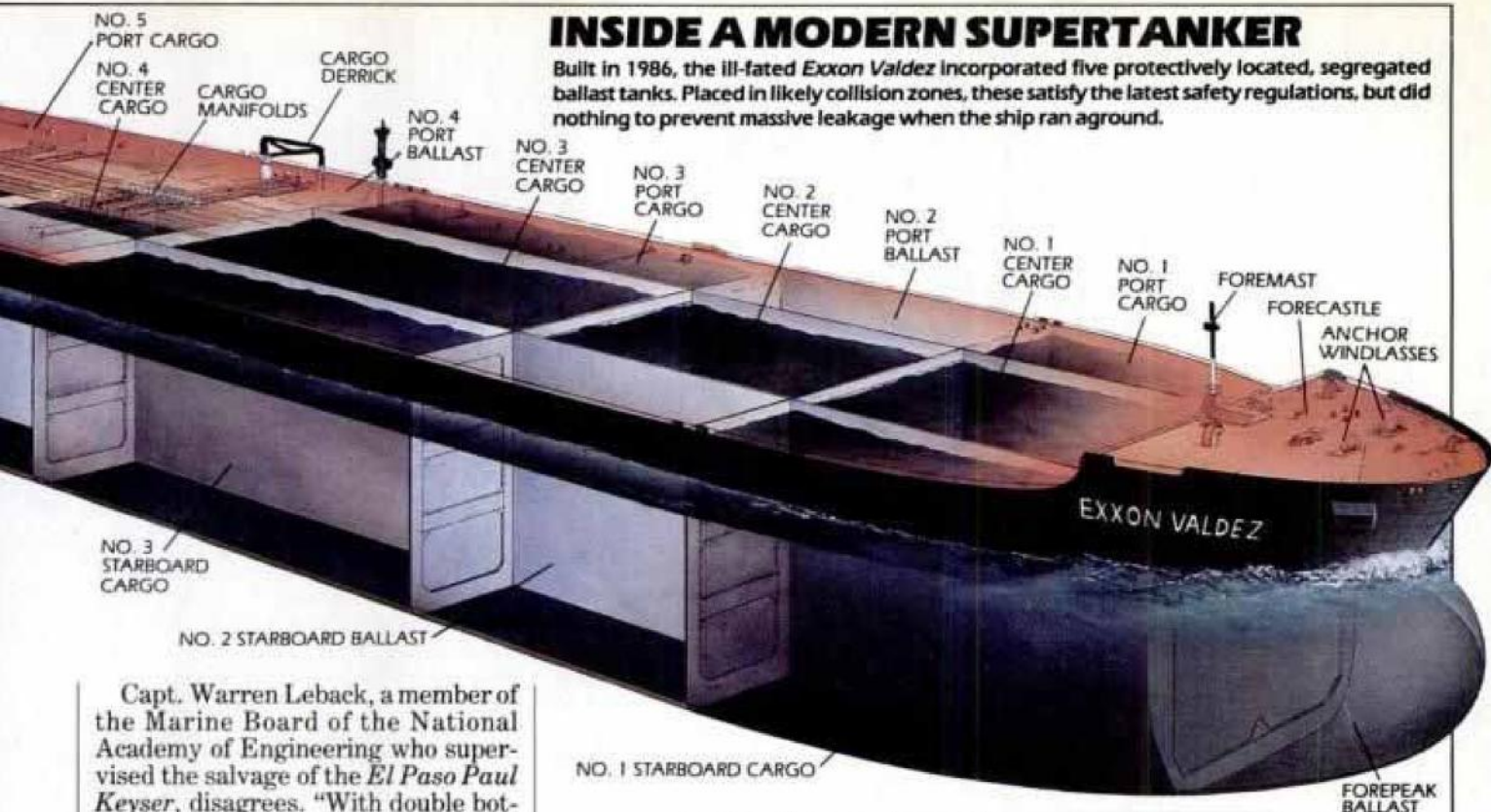
ATLANTIC SUN—Length: 1117 ft. Capacity: 255,850 tons.



ESSO ATLANTIC—Length: 1200 ft. Capacity: 508,731 tons.

INSIDE A MODERN SUPERTANKER

Built in 1986, the ill-fated *Exxon Valdez* incorporated five protectively located, segregated ballast tanks. Placed in likely collision zones, these satisfy the latest safety regulations, but did nothing to prevent massive leakage when the ship ran aground.



Capt. Warren Leback, a member of the Marine Board of the National Academy of Engineering who supervised the salvage of the *El Paso Paul Keyser*, disagrees. "With double bottoms and wing ballast tanks, you're actually in a better position to start a salvage operation," he says, reasoning that having the vessel firmly aground at first makes it easier to work on. Then, when the vessel is ready to be floated, the compartments between the inner and outer hulls provide a space to blow compressed air into, without offloading.

Capt. J.H. Boyd, Navy Supervisor of Salvage from 1973 to 1976, puts it more succinctly. "I view the probability of a major salvage or pollution incident growing out of the grounding of a large single-bottom tanker an order of magnitude greater than that for a double-bottom tanker."

In April of this year, Sen. Brock Adams (D-Wash.) began a new attempt to require double plating. A version of his bill, approved in August, will require the Coast Guard to either produce regulations mandating the safeguard, or explain why it is not needed.



Initial grounding left a gash running from the *Valdez's* forepeak to her starboard slop tank. The 11 colored tanks were all holed. Darkened area was caved in when she came to rest.

Charting the future

Of course, if ships could be prevented from running into things, there would be no need to armor them against impact. Over the past 10 years, devices have evolved that could make the taxing business of navigating a large ship less chancy.

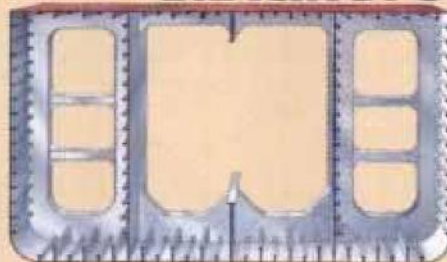
Among the most promising are systems known as electronic charts. These take the data from the navigational equipment already aboard most vessels, including loran, global positioning satellite receivers, depth sounders, radar and gyrocompasses, and integrate them with a computer database of digitized nautical charts.

The result is a single video readout that shows the ship's location and course with respect to the shoreline, bottom contours, buoys, markers and other ships. "It's a very, very powerful display," says Morton Rogoff, head of the Radio Technical Commission for Maritime Services.

Acknowledged to be the most thoroughly developed system of this kind, is one called the Precise Integrated Navigation System made by Offshore Systems of Vancouver. With the aid of radar reflectors placed on shore, the system is able to determine the ship's location to within 1 to 2 meters.

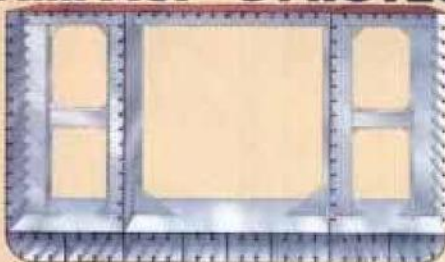
Now in use aboard a handful of Ca-

BRACING FOR IMPACT—3 PROTECTION LEVELS



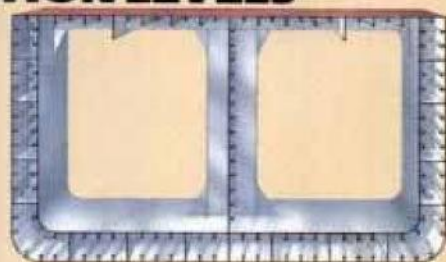
SINGLE SKIN

Light, cheap and traditional, this design prevails despite longer tanker hulls.



DOUBLE BOTTOM

Inner bottom adds strength, and contains oil if grounding breaches outer bottom.



DOUBLE HULL

Required on hazardous chemical carriers, wraparound void space protects in crash.

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..Our New

It can stand on its bow, sit on its stern, spin like a top and tie up at ocean bottom depots or re-supply from other subs

By William Kreh

SECRET of new sub, embodied in Cdr. Haselton's 18-foot model (left), is hull-girdling propellers, enabling ship to perform hydrobatics like a helicopter

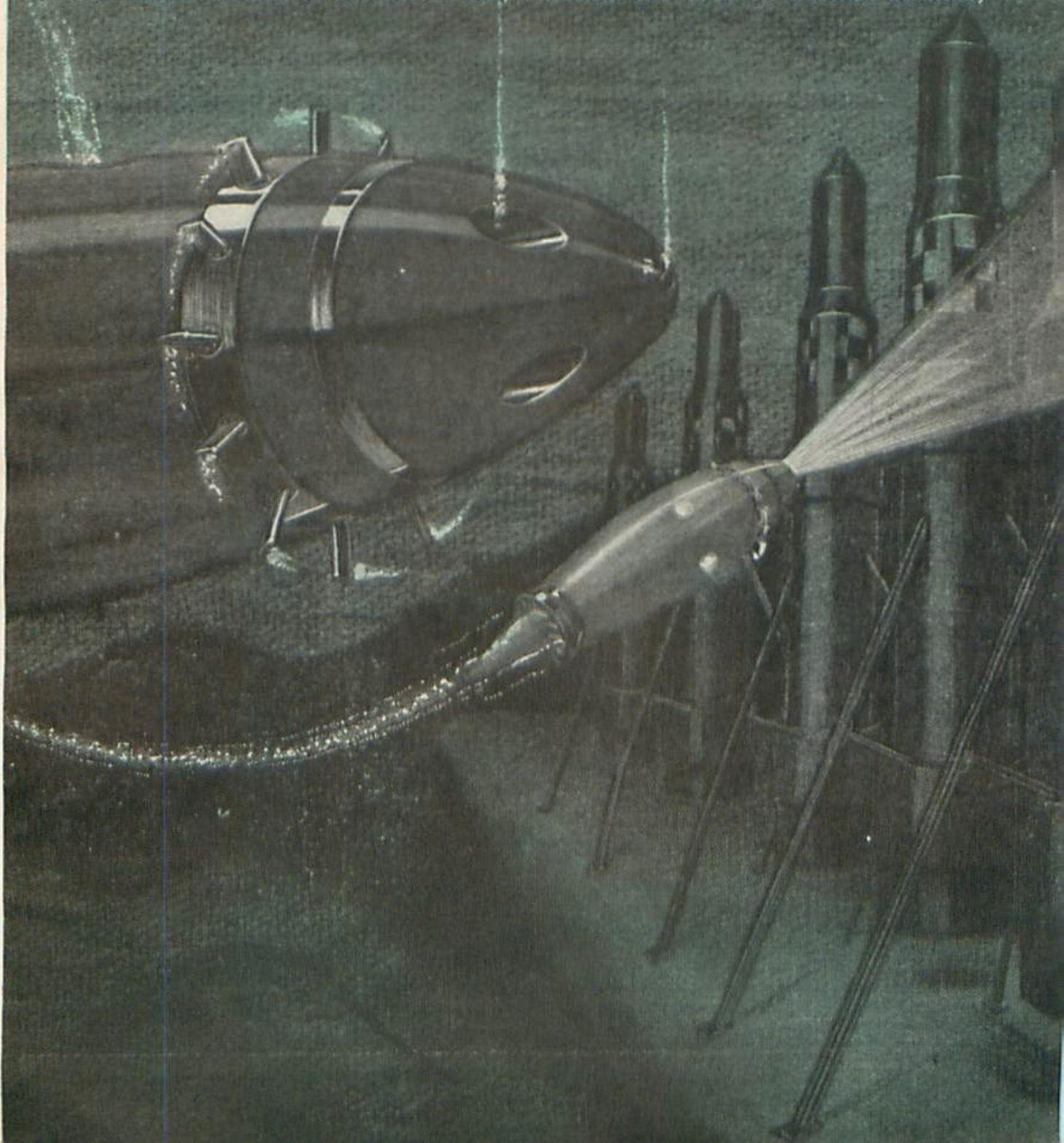
FLEET SUBS in the new configuration may deposit missiles in sea-bottom depot through bow or stern hatches; remotely guided TV camera in vessel with same propulsion system can be launched from missile hatch, as shown, and be retrieved

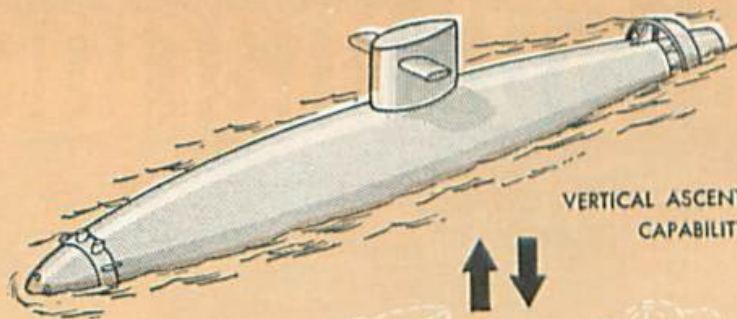
Windmill Submarine

DURING THE PAST few months, Navy experts lining the sides of test tanks have watched an 18-foot model of a wild-looking submarine perform tricks no sub has ever played before.

The sleek, cigar-shaped hull, sporting a ring of whirling blades fore and aft, levitated itself like a helicopter from tank bottom to surface. Then,

without budging forward or backward a single inch, it went to the bottom again like an elevator. It "hovered" at mid-depth, spun on its center in 360° turns. It crabbed sideways, first in one direction, then the other, and indulged in a mad assortment of hydrobatics—such as rolling over, standing on its bow and then on its tail. It also sped around the tank in normal attitude,





VERTICAL ASCENT-DESCENT
CAPABILITY

(A)



360° AFT TORPEDO CAPABILITY
ALLOWS WIRE
GUIDANCE UNDER WAY

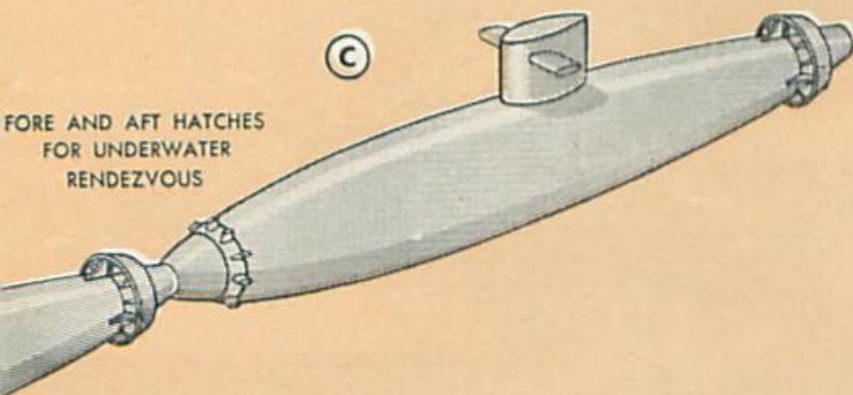
POLARIS
MISSILE
LAUNCH

(B)

16 FT. DIAMETER
BOW HATCH FOR
MISSILE LAUNCH

360° LAUNCH OF
FORWARD TORPEDOES
(WIRE GUIDED)

360° SPIN
TURN RADIUS



FORE AND AFT HATCHES
FOR UNDERWATER
RENDEZVOUS

(C)



VERTICAL BOW
LAUNCH UP TO
16 FT. DIAMETER

(D)

VERTICAL DIVING
MANEUVERABILITY

MISSILE IS DEPOSITED
ON OCEAN BOTTOM
THROUGH 16 FT.
STERN HATCH

UNLIMITED undersea acrobatics can be performed by new sub by controlling blade pitch on counter-rotating tandem propeller rings. Presenting flat blade on downswing, sub rises vertically. Reverse pitch and it descends (A). With front blades pulling one way, rear the other, she swings on her own center (B). She'll stand on her end (D), or connect end-to-end with another sub beneath waves

with the agility of a scared rabbit.

The implications of this performance are vast. The giant model may well be the forerunner of a brand new fleet-type sub that will revolutionize submarine warfare techniques.

The vessel will have no rudders or diving planes, yet will dive deeper than ever thought possible. It will be able to stand upright and "plant" missiles on the ocean floor and later inspect and service them. Or it could assume the same position to fire a Polaris missile out of its bow. It will be capable of rendezvousing and connecting underwater with another submarine for rescue work or to exchange crews. It will be able to fire torpedoes from its stern while revolving around its own dead center, giving it a 360-degree range. And its ability to maneuver freely at great depths will open up new vistas in the science of oceanography.

All this will be possible by using a unique new method of propulsion that is now being studied and developed by the Navy. It's called tandem-propeller propulsion and it uses an "inside-out" electric motor completely submerged in sea water.

This submarine of the future will be propelled by two rings around its hull, one near the bow and the other near the stern. Each ring has 18 to 20 blades projecting from it. Each blade, about 2½ feet long, has independent variable pitch.

The hula-hoop-like rings encircling the submarine run in opposite directions. Various combinations of rotation speed and propeller pitch move the craft in any direction, or at any angle, through the water.

Inventor of the new propulsion system is Commander F. R. "Ted" Haselton, USN, a Naval Academy graduate and veteran submarine officer. In his office at the Un-

dersea Warfare Branch of the Office of Naval Research in Washington, D. C., Haselton showed *Popular Mechanics* the first working model of a submarine using his idea. Most of it was built in his own basement workshop a few years ago.

About 25 inches long, the model was operated by the commander in a tropical fish aquarium and was used to convince the Navy that the tandem propeller idea was worth investigating. For a while, his fellow officers referred to Haselton's office as the "Rotor-Rooter Branch." They don't any more.

Today, the Navy is testing an 18-foot all-aluminum model at the David Taylor Model Basin in Carderock, Md. If this craft, designed both for remote control and for driving by a scuba-equipped operator in a cockpit, proves out, a 25-foot television-guided version now on the drawing boards will be constructed for further tests. After that comes a full-sized operational submarine.

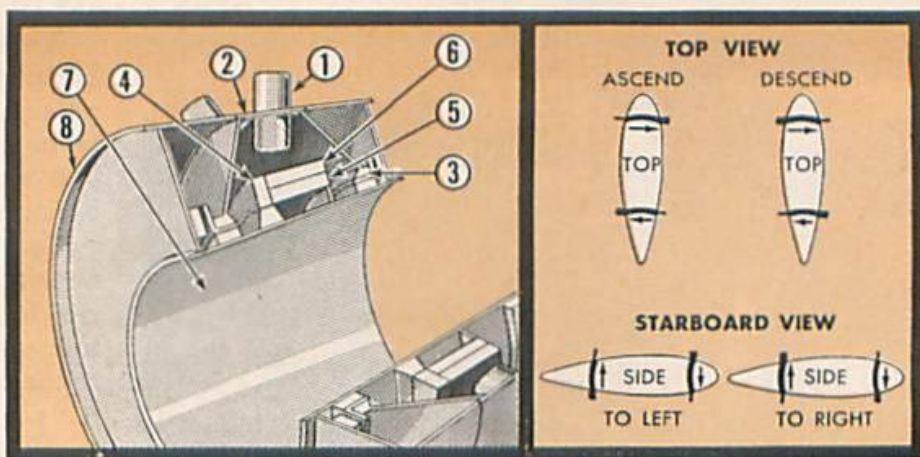
Just how does such a submarine work?

"Moving a tandem propeller submarine forward and backward is done the same way as by conventional propellers," Haselton explains. The difference is that my props turn in opposite directions; the torque produced by one offsets the other.

"To go up or down," he continues, "the pitch of each blade is varied during each revolution so that on the downward half of the propeller's cycle, the pitch of the blades is greater than it is on the upward portion. Thus, if the forward unit is rotating clockwise, its blades will have greater pitch while traveling down the right-hand side of the vehicle than they do going up the left side. Therefore, they will produce a force which moves the submarine

(Please turn to page 208)

ROTOR motor for full-scale sub in cutaway at right shows: 1. individually controlled blade; 2. rotating ring; 3. friction bearings; 4. transformer; 5. A.C. field; 6. rotating armature; 7. pressure hull; 8. superstructure hull. How blade control maneuvers sub is shown at the far right



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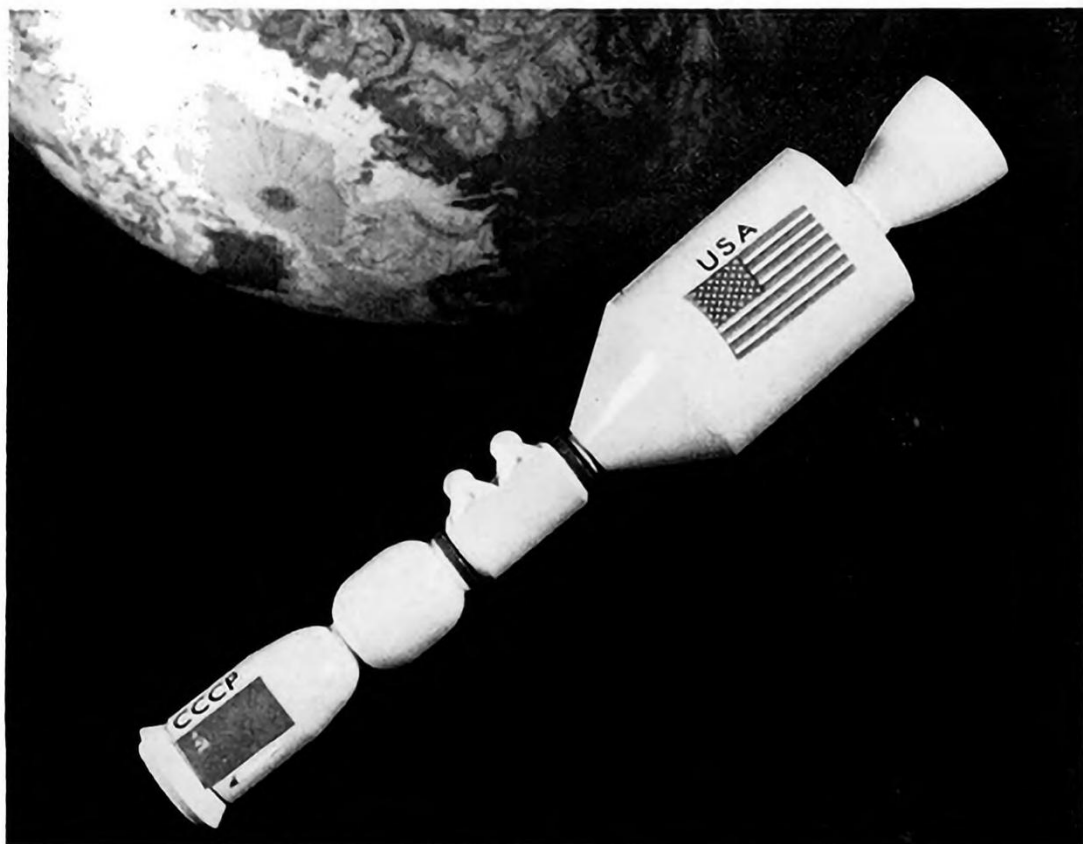
How We'll Team Up with the Russians in Space



By
WERNHER von BRAUN
PS Consulting Editor, Space

Linking up an Apollo and a Soyuz in orbit, just announced for 1975, may open the way to space rescues, international space flights, and possibly even a U.S.-Russian manned voyage to Mars

First US-USSR space docking is previewed by NASA model. Linked in Earth orbit, left to right, are Russian two-segment Soyuz spacecraft; new Docking Module; and American Apollo spacecraft.



The United States and the Soviet Union, rivals in space flight for 15 years, have decided to carry out their first joint manned mission in history. Scheduled for 1975, an exciting project to join an American Apollo and a Russian Soyuz for two days in Earth orbit is the highlight of an agreement on space cooperation signed by President Nixon and Premier Kosygin at the Moscow summit meeting last May.

Planned during the Apollo-Soyuz mission are visits by the spacemen from one ship to the other; and some joint scientific experiments, probably simple, still to be chosen. Mainly, however, the mission will be a practical flight trial of an extraordinary new piece of space equipment called a Docking Module—a combination docking-system adapter and air lock, which will permit linking U.S. and Russian manned spaceships despite their incompatible docking hardware

and their different cabin atmospheres.

Successful trial of the new Docking Module could open the way to joint US-USSR space flights of every description. A definite early goal will be equipment for international space rescues, so that our astronauts could come to the aid of Russian cosmonauts in distress, and vice versa.

The newly signed agreement calls specifically, too, for compatible docking systems permitting "joint scientific experiments in the future." Possibilities seen in current speculation range from visits to each other's space stations, up to projects as ambitious as a manned voyage to Mars—sharing what might otherwise be its prohibitive cost.

So, while the Apollo-Soyuz Test Mission is the only joint space flight so far scheduled, hopes run high of what it may lead to.

The first US-USSR space flight. Here is the flight plan of the 1975 mission:

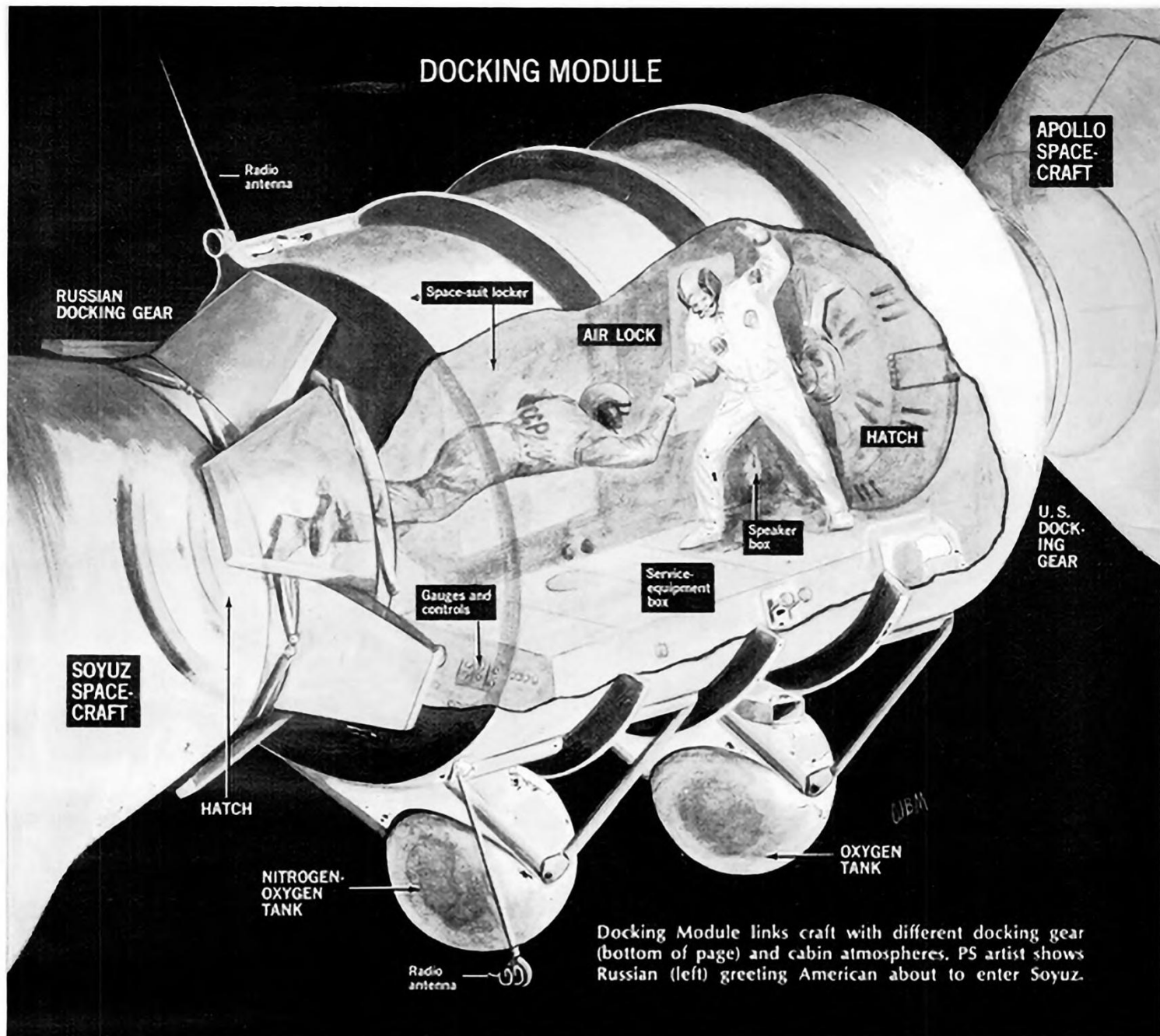
A two-stage Saturn IB rocket will boost an Apollo spacecraft, carrying two or three astronauts, into a low Earth orbit about 125 statute miles up. After separation from the second rocket stage, the Command and Service Module will turn around, dock with a Docking Module inside the rocket's nose, and extract it—much as the Lunar Module is extracted in our Apollo lunar missions. The weight of spacecraft and Docking Module will total about 33,000 pounds.

The plane of the orbit, inclined 51.6 degrees to the equator, will take the Apollo over the USSR launch site in Soviet Kazakhstan, about 100 miles northeast of the Aral Sea—the Baikonur-Tyuratam Cosmodrome.

One to several days later, the Soyuz spacecraft will be launched with two cosmonauts aboard. Its own well-proven launch vehicle will put it into an orbit about 165 statute miles high.

Then the Apollo spacecraft will ac-

DOCKING MODULE



Docking Module links craft with different docking gear (bottom of page) and cabin atmospheres. PS artist shows Russian (left) greeting American about to enter Soyuz.

tively maneuver itself into a station-keeping position with the Soyuz, with the help of the Apollo radio and optical guidance systems.

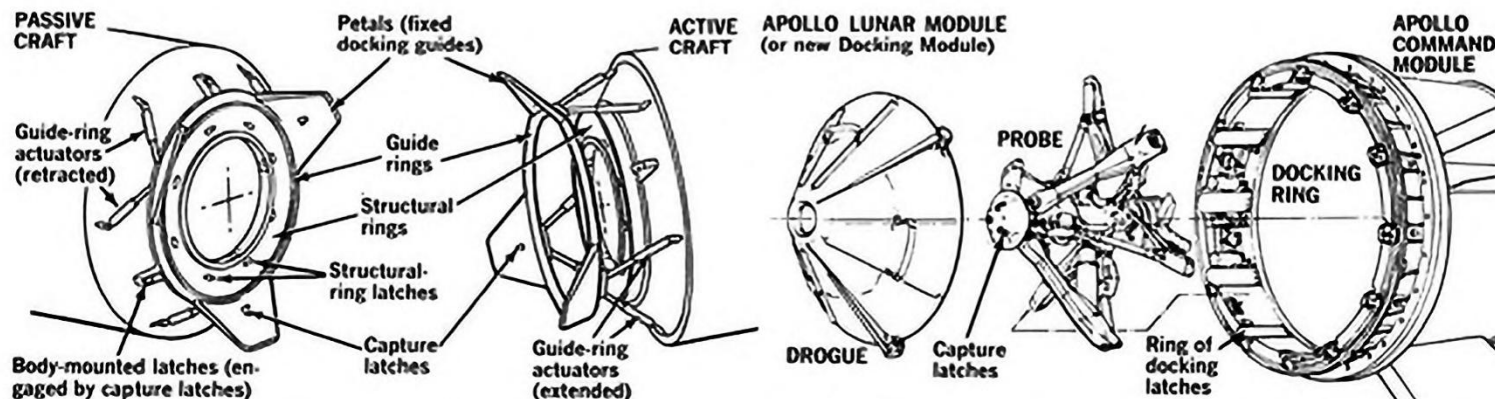
From this position Apollo will proceed to dock with Soyuz, using the new Docking Module—shortly to be

described—and a novel TV docking-alignment system.

"Welcome aboard!" An Apollo crewman's visit to the Soyuz is expected to begin a round of calls upon one another. So the historic handshake as Americans and Russians first

meet in space may take place inside the Soyuz. Or possibly, as PS's artist visualizes it here, a gracious Russian host might meet the American halfway in the Docking Module to extend a personal "welcome aboard" and

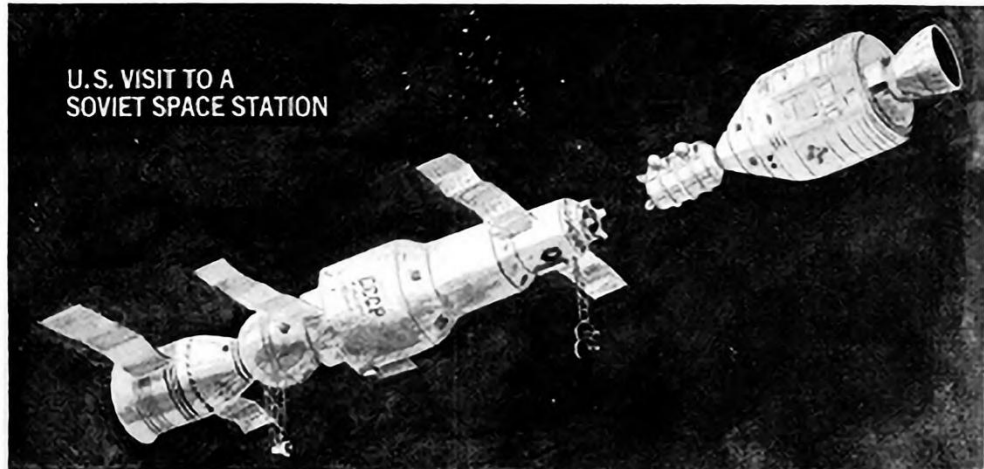
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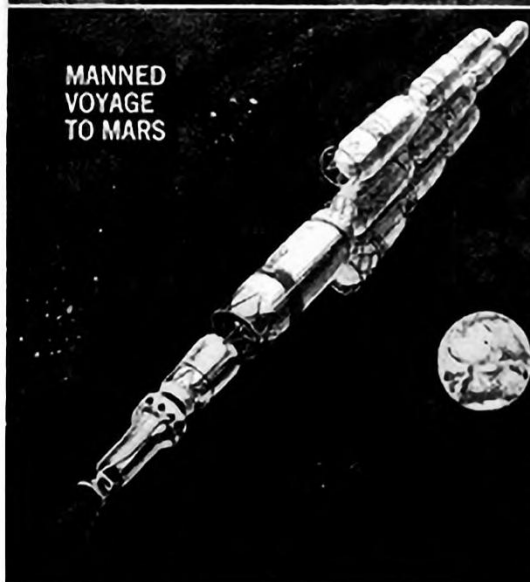
In Russian-favored docking system, latches on petals of one craft engage latches on body of other. Petals' retractable ring draws two craft tight. Structural-ring latches complete docking.

In U.S. docking system, latches on tip of probe engage opening at center of conical drogue. Retractable probe pulls two craft together until ring of automatic latches secures them tightly.

U.S. VISIT TO A
SOVIET SPACE STATION



MANNED
VOYAGE
TO MARS



SPACE RESCUE



Possible future US-USSR missions, still unscheduled but now seen open to speculation, include these examples. Top, Apollo visits a Salyut space station manned by Russian crew of a Soyuz (already attached). Above left, manned voyage to Mars illustrates costly project that might become feasible jointly. Above right, international space rescues of each country's spacemen by those of other one are called a primary goal of present American-Russian plans. Picture shows what may be nearest thing

yet to a suitable vehicle—a U.S. “Skylab crew-rescue command module,” to which a standard Apollo Command Module would quickly be converted by a new kit increasing its seating capacity from three to five. (Two men go up, five come back.) Adding a Docking Module as shown would ready it to aid a Soviet craft in distress. In picture here, it could be about to cast off from a stricken spaceship (not shown) with the rescued cosmonauts occupying the extra places inside for the return trip.

escort him back into the Soviet craft.

Next a Russian will accompany the astronaut back to the Apollo.

After two days of visiting and science experiments, the two spacecraft will separate. Soyuz will parachute to a land site in the USSR; and Apollo, to a splashdown in the western Atlantic, for recovery by a naval vessel.

The Docking Module. Both in docking the two spacecrafts in orbit, and in all movements of crewmen between them, the new Docking Module plays a key role. It is a cylindrical structure, about five feet in diameter and 10 feet long, with room inside for two men in space suits—which would probably be donned only in an emergency.

Its opposite ends will have docking hardware suiting that of the U.S. and Russian spacecraft, respectively. Thus the Docking Module serves me-

chanically as an adapter, to link the otherwise incompatible docking systems—and enable the existing, flight-proven Apollo and Soyuz spacecraft to dock with each other.

The Docking Module’s “American end,” like an Apollo Lunar Module, will contain the conical drogue of the standard U.S. probe-and-drogue docking system.

Its “Russian end” will be fitted with the ring-and-petal docking system preferred by the Soviets.

Drawings on the preceding page compare the two types. The Soyuz’ system has the attraction of being a “peripheral” one—entirely outside the central hatchway, which it leaves unobstructed. Our own probe-and-drogue system, a center-line one, inconveniently blocks the hatchway and requires hardware to be detached and stowed out of the way, after docking, before a crewman can pass

through it to the other spacecraft.

Second major role. No less important is the Docking Module’s role as an air lock, to enable crewmen to transfer between spacecrafts with different cabin atmospheres.

While the astronauts in the Apollo breathe pure oxygen at a pressure of only five pounds to the square inch, the cosmonauts in the Soyuz are used to a luxuriously airlike nitrogen-oxygen mixture at normal 14.7-pound atmospheric pressure. A gradual changeover in the Docking Module’s variable atmosphere prepares a crewman of one craft to enter the other.

How long it takes an astronaut from the low-pressure Apollo to adjust to the Soyuz’ three-times-higher pressure depends solely on the rate of pressure buildup his eardrums can stand without undue discomfort. NASA estimates that no longer than 25 minutes in the Docking Module should suffice. The problem here resembles that of a descending scuba diver.

Entering Apollo from Soyuz is another story. This time the problem, like that of an ascending diver, is to avert the “bends”—decompression sickness due to release of bubbles of nitrogen previously dissolved in the blood, in going to lower pressure. A stay of approximately two hours in the Docking Module will be required for slow depressurization and equally important prebreathing of pure oxygen.

The entrance-and-exit hatches at each end of the Docking Module will be opened, one at a time, only when its atmosphere’s pressure and composition match those of the spacecraft beyond.

Obviously these preliminaries for visiting rule out any scampering back and forth between Apollo and Soyuz. Further limitations are the agreed-upon “ground rules” that an American will be in the Apollo, and a Russian in the Soyuz, at all times; and that two men will be the maximum in the Docking Module at once. Finally, the Docking Module’s gas supply (carried externally) sets a limit; it suffices for a total of three round trips by two crewmen.

The story behind the mission. The agreement signed during the Moscow summit meeting gives the final go-ahead for plans under discussion with the Soviets since April 1970, when Dr. Thomas Paine, then Administrator of NASA, informally proposed the desirability of compatible docking units enabling astronauts or cosmonauts to come to each other’s help in case of difficulties. This suggestion led to a first meeting at Moscow in October 1970 between members

[Continued on page 118]



SHOP TALK

By ROBERT P. STEVENSON

How to adjust your shop tools to suit your height

A reader posed an interesting question some time ago: For a man of average height, he asked, what are the recommended heights for shop equipment to assure both safety and ease of operation? He specifically wanted to know optimum dimensions from floor to tabletop for a workbench, table saw, radial-arm saw, jointer-planer, and drill press; from the floor to the centerline of a woodworking lathe; and from the floor to the working surface of a belt-disk sander.

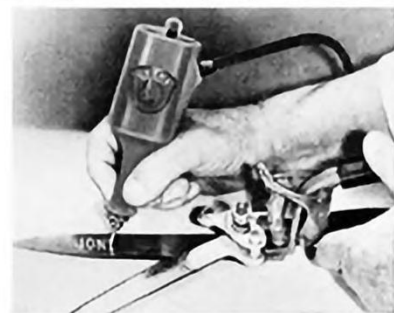
We referred the question to the Power Tool Institute. J. L. Stackhouse Jr., senior design engineer for Emerson Electric Co. (a PTI member), pointed out that ANSI (American National Safety Institute) O1.1-1971 Safety Requirements for Woodworking Machinery state:

For maximum efficiency, it is recommended that the height of the table or point of operation above the floor for various machines be approximately as follows for operators of average (69.3") stature:

Circular saws (hand fed)	36"
Circular saws (power fed)	32"
Band saws	46"
Shapers	36"
Jointers	33"
Lathes	41"
Sanders	36"
Radial-arm saws	39"

These heights are recommended in two recent books devoted to the subject. Tool stands and legs are usually made adjustable to provide variation both up and down from the 69.3" average. The list does not include drill-press table height since this is adjustable by design. Workbench height would be about 36".

Engraving tool helps police recover stolen items



Police departments in more than 100 communities throughout the U.S. have an effective new procedure for recovering stolen articles—or even preventing thefts in the first place. The program is based on one that has been running in Monterey, Calif., since 1963. Under the program, the local police or other sponsoring agency lends an electric engraving tool to families to inscribe their driver's-license number on all items of value in the household.

Participating families place "Project Theft-Guard" stickers at their front and back doors, also on bicycles. Costs for developing materials used in the program are underwritten by Dremel Manufacturing Co., Racine, Wis. 53401. Dremel makes electric engravers. These write like a pencil on metal, plastic, wood, and other materials. In San Antonio, Tex., Holy Cross High School has sponsored the program as a means of helping to raise school funds.

New books for the craftsman's shelf

When it comes to framing pictures, you can do a lot of good things with stock molding available at building-supply dealers. A new book shows good examples and gives the required know-how. The book is *Handmade Picture Frames from Simple Moldings* by Ellwood Bauhof and Robert C. Chapin Jr., published by Countryside Press, care of Farm Journal, W. Washington Sq., Philadelphia (\$1.95).

A 44-page volume from American Edelstaal, Inc., 1 Atwood Ave., Tenafly, N.J. 07670, is designed both as a general handbook on metal-lathe practices and an operator's manual for this company's compact Unimat. It's priced at \$1 for regular-mail delivery.

Other interesting new books I've seen include: *The Art of Making Wooden Toys* by Peter Stevenson (Chilton, \$9.95); *Complete Book of Home Repairs and Maintenance* by Jackson Hand (Popular Science, \$8.95); *Home Book of Smoke Cooking* by Jack Sleight and Raymond Hull, including how to build several smoke ovens (Stackpole, \$7.95).

Joining the Russians in Space

[Continued from page 78]

of NASA and the USSR Academy of Sciences, which resulted in a basic agreement to study compatible rendezvous-and-docking systems for manned spacecraft.

At a second meeting in June 1971 at Houston, it was agreed to study two candidate docking missions: an Apollo to a Salyut space station, and a Soyuz to a Skylab space station.

Apollo and Soyuz chosen. In a third meeting at Moscow in November-December 1971, the technical feasibility of the Apollo-Salyut mission was confirmed, but a number of possibly serious problems of cost and scheduling were seen. The Soyuz-Skylab mission was scratched; Soyuz could not reach Skylab's orbital altitude of 270 statute miles. Further studies led to the decision, in an April 1972 Moscow meeting, to use Apollo and Soyuz. The Soviets selected Soyuz for this mission mainly because of their practical experience with this spacecraft, which has been their primary manned space vehicle since 1967.

Other agreements reached in the series of meetings covered such varied details as hard schedules; who would have what functions of flight control and command; how and where the two crews would be trained to understand each other, and how much familiarity with each other's languages would be needed.

Key figures in these meetings were Dr. George M. Low, Acting (later Deputy) Administrator of NASA, who headed the U.S. delegations, and Prof. M. V. Keldysh, President, Academy of Sciences of the USSR. Dr. G. S. Lunney of NASA and Prof. K. D. Bushuyev of the USSR Academy, who headed two of the Joint Working Groups on technical and operational questions, have been appointed as Apollo-Soyuz Test Project Directors.

Projected schedule. NASA has announced it will begin manufacture of the Docking Module this summer. Building and testing it will take two years—and the 1975 mission date is seen as the earliest when all preparations can be comfortably completed. Soviet engineers will be working side by side with those of NASA, probably in both countries.

Hopefully, the Apollo-Soyuz mission will be only a beginning. The Moscow accord announced that future generations of manned spacecraft of both the U.S. and the Soviet Union will be capable of docking with each other. And many a U.S. astronaut reportedly is boning up on speaking Russian. [E]

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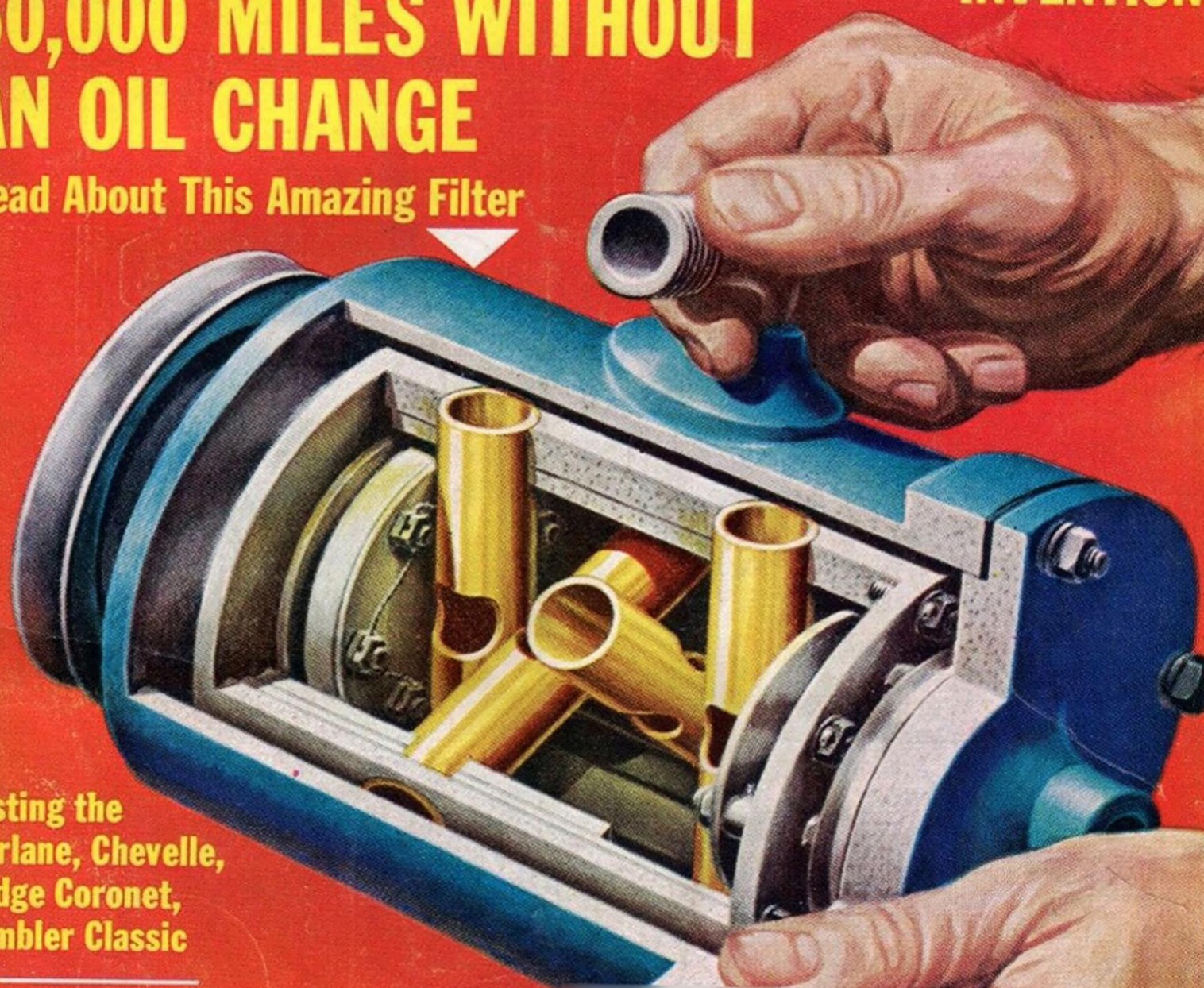
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When Will

An expedition on the way to Mars

"Mars Mission Module" envisioned in NASA drawing is manned earth-to-Mars spacecraft containing two other capsules: excursion module for descent to Mars' surface, and re-entry module for return to earth. Dish-shaped appendages shown extended at sides are solar collectors for generating power on the long interplanetary voyage.

A space authority takes a look at the rocket ship, equipment, and possible date for a manned interplanetary expedition

By Dr. Wernher von Braun

Director of NASA's George C. Marshall Space Flight Center, Huntsville, Ala.

Dr. von Braun, seated, gives Rep. Roman C. Pucinski his views at House hearing on proposed National Science Information Center.



NOW that we have an unmanned spacecraft on the way to Mars, and have already sent a highly successful one past Venus, the question is being heard, "When may we expect manned interplanetary expeditions?" For a realistic answer, let us appraise the magnitude of the task and compare it with our present capabilities.

Suppose we try to describe, as best we can today, what the first manned expedition to Mars may really look like:

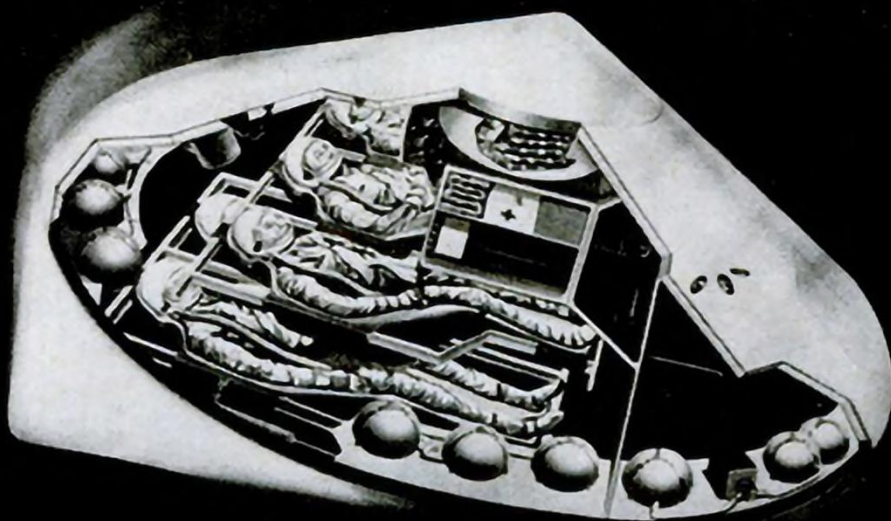
Place of departure. It is fairly certain that a manned Mars expedition will not start from the earth's surface—but from a low "departure orbit" around the earth. There, the interplanetary ship will be assembled, from loads hauled up by earth-to-orbit cargo rockets.

Size of crew. A Mars expedition may require a crew of 6 to 10, or more. For an interplanetary voyage, there are several arguments for a bigger crew than the trio of astronauts who will make the much briefer Apollo moon trip. The length of the Mars expedition increases the chances that a crew member might become sick and require a doctor's care, as well as replacement. Adding a few crew members can give

We Land on Mars?

The homecoming— full-speed re-entry

Crewmen lie on couches, arranged in two tiers, to take G forces of hitting earth's atmosphere at high speed, in NASA conception of Mars expedition's re-entry capsule. Dispensing with rocket braking saves having to haul propellants for it all the way to Mars and back.



the expedition much greater scientific usefulness. And since the equipment will be more complex than for a moon trip, it will need more monitoring and maintenance.

The interplanetary rocket ship. For its power maneuvers, in earth orbit and near Mars, we can assume that the spaceship will be designed to use one of these two forms of propulsion:

- High-energy chemical engines, burning liquid hydrogen and liquid oxygen.
- Nuclear engines, of Rover type with a solid core, using liquid hydrogen as the sole propellant. These would provide nearly twice the "specific impulse" (a measure of propulsive efficiency) of chemical engines.

Payload. Besides the weight of the ship itself, its crew, and its propellants, we shall have to plan for sizable items of payload, including:

- Enough oxygen, food, and water to supply all the crew members for the duration of the expedition.
- A simple radiation shelter—since bursts of solar radiation, reasonably predictable for short periods like that of an Apollo round trip to the moon, cannot be forecast for the long time

span of a voyage to a planet and back.

- A spinning crew compartment to provide artificial gravity, or at least a centrifuge for occasional exposure to it.
- Radio equipment capable of covering interplanetary distances reliably.

To arrive at any estimate of what all these items will total, we must now examine such things as the distance, time, and flight plan in more detail.

Distance. Comparison with a flight to the moon will help to put an interplanetary flight in perspective. The average distance between earth and moon is 238,860 miles, and a typical Apollo trajectory is only slightly longer.

Venus' and Mars' closest approaches to earth are 26 million and 35 million miles, respectively. But Mariner II had to travel along a curved circum-solar trajectory of 180 million miles to intercept Venus. Mariner IV, now headed for Mars, will have covered 325 million miles before getting there.

Flight times. A typical one-way flight to the moon requires 2½ to three days. Mariner II's flight to Venus took almost four months. Mariner IV will be on its way to Mars for eight months. These are one-way flight times. However,

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MADE IN OHIO BY ROBOTS

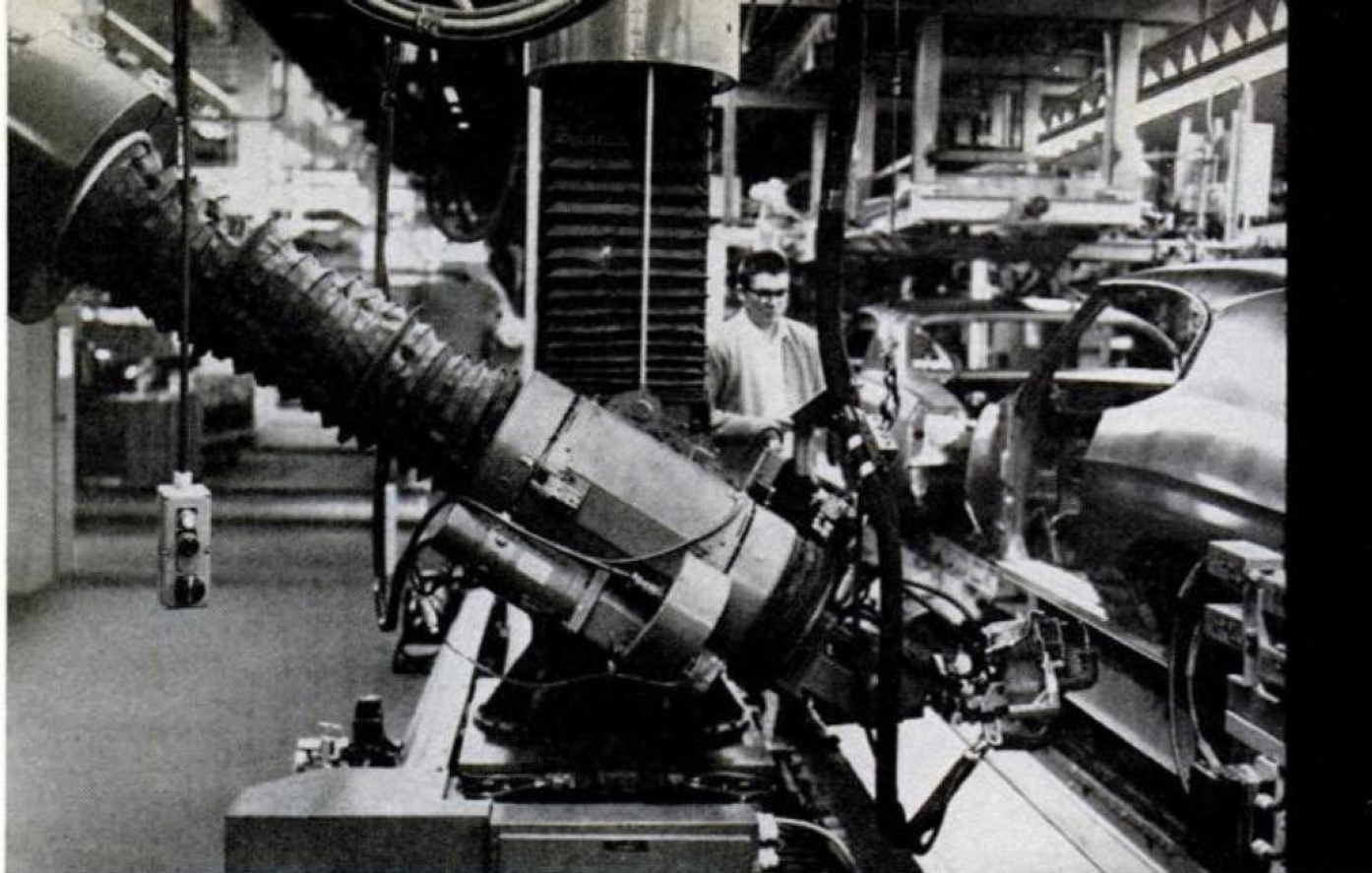
Chevrolet's new Vega—a one-ton wonder on a 97-inch wheelbase—is getting the quality built in on an assembly line 'manned' by machines with hands

By ROBERT LUND, Detroit Auto Editor

Illustration by Roy Grinnell

THEY'RE NOT MAKING THEM like they used to at General Motors' new Lordstown, Ohio, assembly plant. They're making them in the most modern, automated, robotized carmaking complex in the world, a plant that could become the copybook layout for new auto factories for the next 25 years.

GM is using apprentice robots at Lordstown, an idea that may be as much of a milestone in automaking as the



continuously moving assembly line. Where the moving assembly line brought the car to the worker so he could get his hands on it from a stationary position, Lordstown is a step toward producing cars virtually untouched by human hands.

Detroit visionaries are convinced the day will come when an automobile salesman will take your order, punch out the specifications on a machine that will feed a tape directly into the nearest assembly plant, programming the vehicle for production. From this point on, the machine will take over. As soon as the salesman completes his description of the order, the machine will flash back an acknowledgement: "Shipment scheduled for Sept. 27, 14:23 hours."

GM's response to such speculation is a haughty, "Bosh!" The untouched-by-human-hands theory is so farfetched, GM contends, it doesn't deserve the dignity of a "No comment."

The reason GM is reticent about claiming credit for its pioneering at Lordstown is obvious. The United Auto Workers Union is opposed to any movement that might take jobs away from its members. GM has had problems in the past trying to automate its

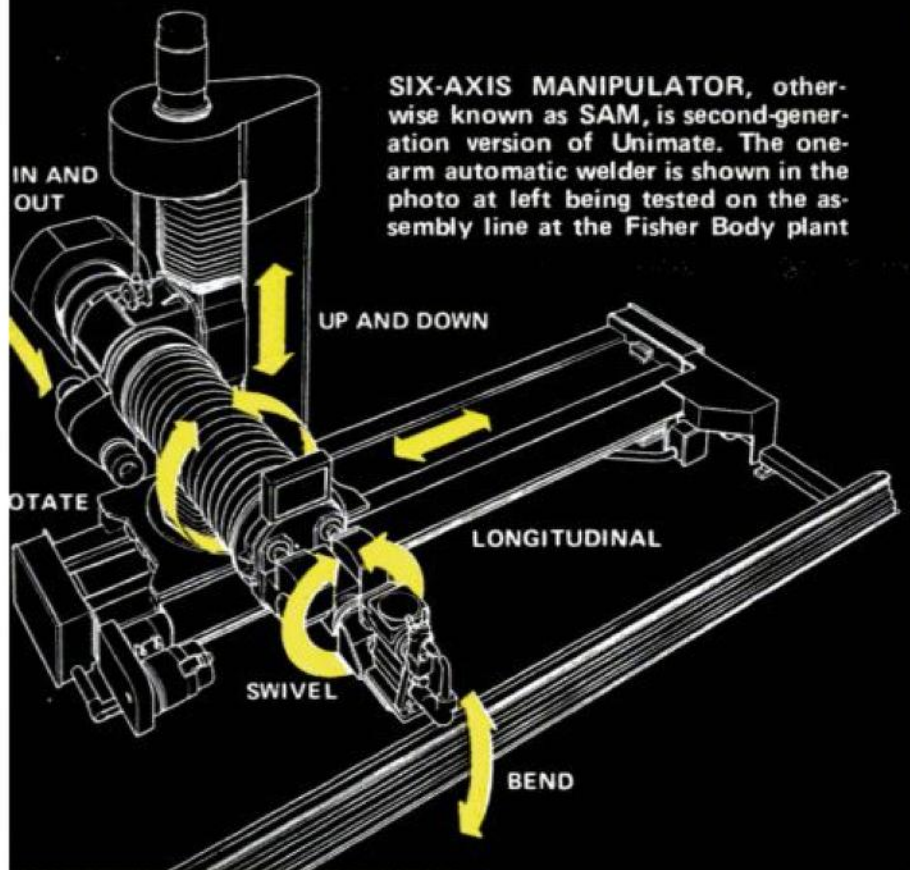
plants and it doesn't want to fuel the fire by discussing the idea of robot factories.

But Lordstown is the most robotized auto assembly plant ever, whether GM claims the title or declines it.

Lordstown is actually two plants. One is a metal fabricating plant operated by Fisher Body Div. Fisher stamps out sheet metal and does much of the sub-assembly work on body parts—doors, deck lids, fenders.

A second facility, where the car is assembled, is about a city block away from the Fisher plant. The second plant is operated jointly by Fisher and Chevrolet. Both plants are devoted to production of a single car—Chevrolet's mini, the Vega. The main assembly plant has a single production line, off of which GM can produce Vega in four body styles—sedan, fastback, wagon and panel truck.

The two plants are connected by a covered conveyor line. Finished sheet metal can be shipped off the end of the line at the Fisher factory to the appropriate station in the assembly plant without being exposed to the elements. There's no waiting for parts to be trundled from one plant to another, no tie-



SIX-AXIS MANIPULATOR, otherwise known as SAM, is second-generation version of Unimate. The one-arm automatic welder is shown in the photo at left being tested on the assembly line at the Fisher Body plant

welded. Jigs and fixtures are then removed and the Unimates take over, welding the vehicle together. Something over 85 per cent of all welding on Vega is done by machine.

GM avoids making any gee-whiz claims for machine welding over hand welding, but there are definite advantages with the machine method. The weld is always the same, leading to better quality and presumably a more reliable product, and the machine never takes a day off, although it is subject to wear and down-

time for replacement or repair.

ups because trains or trucks can't travel, no risk of parts being damaged in handling or transit, no panic phoning back and forth between feeder plant and mother plant. Except for the Vega engine, which is made at Tonawanda, N.Y., Lordstown is a self-contained operation.

GM doesn't want to take a position of championing machine over man. It's not good politics. But it's significant that GM claims Vega, the least expensive car in its catalog, will be as fine and tight an automobile in terms of quality construction as any car GM has ever produced. Including Cadillac. In a company where the powers-in-command inevitably soft-pedal and understate, that's a mouthful.

The machines-in-lieu-of-men that cause GM to bite its tongue when the word "robot" comes up are located in the assembly plant. The machines are called Unimates. The name comes from the Danbury, Conn., company, Unimation, Inc., that produces the equipment.

Automatic welding is not new to the auto industry and the limited use to which GM is putting its robots is not likely to win the auto firm an award for trailblazing. The Unimates are capable of far more complicated jobs than GM has assigned to them. As I gathered on an unofficial trip to Lordstown, the company appears to be feeling its way with its benign Frankensteins. What can they do? How reliable are they? How will the union react?

GM has 26 Unimates at Lordstown, the largest crew of industrial robots in a single plant in the United States. It might be more accurate to say the company owns up to having 26 machines, because it would be unlike GM not to have a spare or two on standby for emergency duty if one of the "soldier" machines conks out. The robots are paired up opposite each other in twos, 13 on each side of the line.

Initially, the 26 units will be limited to a single function—welding body parts. Just before the line reaches the Unimates, the underbody and sides of the car are brought together and tack

The company that supplied GM with the equipment says it has some of the answers. The robot's "birth certificate" as supplied by Unimation, Inc., reads:

"The Unimate robot is a mechanical arm controlled by a solid-state memory

(Please turn to page 204)